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BENCH-SCALE PERFORMANCE TESTING AND ECONOMIC ANALYSES OF ELECTROSTATIC DRY COAL CLEANING

by

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16. ABSTRACT
The report gives results of preliminary performance evaluations and economic analyses of the Advanced Energy Dynamics (AED) electrostatic dry coal-cleaning process. Grab samples of coal feed product coals were obtained from 25 operating physical coal cleaning (PCC) plants. These samples were analyzed for ash, sulfur, and energy content and splits of the original samples of feed run-of-mine coal were provided for bench-scale testing in an electrostatic separation apparatus. The process showed superior sulfur removal performance at equivalent cost and energy recovery levels. The ash removal capability of the process was not evaluated completely: overall, ash removal results indicated that the process did not perform as well as the PCC plants.

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a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Energy	Pollution Control	13B	14G
Coal		Stationary Sources	08G, 21D	
Coal Preparation		Coal Cleaning	08I	
Electrostatics		Physical Coal Cleaning	20C	
Ashes			21B	
Sulfur			07B	

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ABSTRACT

This report presents the results of preliminary performance evaluations and economic analyses of the Advanced Energy Dynamics (AED) electrostatic dry coal-cleaning process. Work on this project was performed in concert with Versar, Inc. and this report covers the work of both AED and Versar.

Grab samples of coal feed product coals were obtained from 25 operating, physical coal cleaning (PCC) plants by Versar. These samples were analyzed for ash, sulfur, and energy content and splits of the original samples of feed run-of-mine coal were provided to AED for bench-scale testing in an electrostatic separation apparatus.

This report was prepared by Advanced Energy Dynamics, Inc. under contract 68-02-3662 with the U.S. Environmental Protection Agency. This report covers the period of September 1980 to July 1983.

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CONVERSION TABLE

English		Metric
1 inch (in.)	=	25.4 millimeter (mm)
1 pound (lb)	=	2.2 kilogram (kg)
1 ton per hour (tph)	=	1.10 metric tonnes per hour
1 Btu per pound (Btu/lb)	=	2326 Joules/kilogram (J/kg)

ACKNOWLEDGMENT

Versar and AED would like to acknowledge the assistance and direction provided by David Kirchgessner and James D. Kilgroe of the U.S. Environmental Protection Agency.

Acknowledgment is given to Versar, Inc. which collected and analyzed coal samples from 25 coal preparation plants. Versar also performed economic evaluation of commercial coal preparation contained in this report. Major Versar contributions are included in Section 4, "A. Coal Sampling and Analysis"; Appendix A; and Appendix C. The Versar project director was Lee McCandless, and the project manager was Bekir Onursal. The task managers were Robert Cochran and Margaret Young. Thanks to Thomas Chambers, Mike Craig, James Parker, and John Quander, who contributed to various parts of the project. The Versar work was conducted under EPA contract 68-02-3181, Task 3.

The cooperation of management and operators of the 25 coal preparation plants from which samples were collected is gratefully acknowledged.

The AED project director was Stanley R. Rich. The task engineer was David Whitlock. Thanks are gratefully extended to David Schirmer and Sandra Ryan, who contributed materially to the completion of this project.

SECTION 1

INTRODUCTION

As the most abundant fuel resource in our nation, coal is destined to play a dominant role in the energy future of the United States. Unfortunately, coal is generally also the dirtiest fuel in our energy supply mix. For this reason there is a continuing interest, both in government and the private sector, in novel processes which offer the promise of being able to upgrade the fuel quality of available coals. Advanced Energy Dynamics, Inc. (AED) has developed a proprietary dry coal-cleaning process ([1],[2]) which has shown encouraging results in a number of preliminary tests. This process removes inorganic matter (largely ash-forming minerals including pyrite, the source of inorganic sulfur) from pulverized coal by means of a proprietary electrostatic separation process. There are two major advantages of the AED electrostatic dry coal-cleaning process over conventional coal-cleaning processes. First, the coal is crushed to very fine particle sizes, liberating a large portion of the mineral matter and pyritic sulfur from the organic coal structure and increasing the potential for ash and sulfur reduction. The second advantage is that the coal is processed in a dry state avoiding costly dewatering and drying requirements.

Technical problems associated with development of the process include the difficulty of achieving efficient particle separations for very fine coal and the difficulty of handling large quantities of fine sized coal. Also, fine coal must be handled in a manner which avoids explosions.

The purpose of this project was to develop a broader information base on the performance of the original AED Tech 1 Process (not to be confused with subsequently improved processes) on various coals and to provide information which would allow preliminary comparisons of the Tech 1 Process with conventional physical coal-cleaning (PCC) processes. The ultimate objective was to provide a basis for assessing the merits of the technology in the context of other coal-cleaning techniques. The project was performed as a joint effort by Versar and AED. The methodology adopted for the evaluation involved the testing of the Tech 1 Process for removing of ash and sulfur from selected coals and as qualitative comparison of the performance with conventional coal cleaning plants. In addition, the estimated costs of the Tech 1 Process were compared with those for operating (i.e., existing) physical coal-cleaning (PCC) plants processing representative minemouth coals. Raw coal samples were furnished to AED by Versar. These samples were portions of larger samples collected in the field at the PCC plants.

The scope of the project involved:

- Identification of the representative coal seams in the United States.
- Selection of the PCC plants processing coal exclusively from these seams.
- Scheduling of the sampling trips to selected PCC plants.

- Collection of the 29 feed and cleaned coal samples from 25 PCC plants.

- Splitting the samples into various fractions.

- Testing of the feed coal samples with the AED bench-scale coal cleaning system.

- Analysis of all feed and clean coal samples for chemical properties.

- Evaluation of the performance of AED's bench-scale, coal cleaning unit in removing sulfur and ash from two coal particle size ranges.

- Cost analysis of the PCC and AED technologies.

- Comparison of the performance and economics of the Tech 1 Process with conventional PCC plants.

This report contains a review of the above activities, and draws those conclusions which can be supported by the data. Recommendations for further study/evaluation are offered.

SECTION 2

SUMMARY AND CONCLUSIONS

This research program was designed to provide support to the U.S. Environmental Protection Agency for the evaluation of the coal-cleaning process being developed by Advanced Energy Dynamics, Inc. (AED). The methodology adopted in this study involves an evaluation of the performance of the AED Process and comparison with physical coal cleaning (PCC) plants presently in operation.

Representative coal seams in the United States were identified, and 25 PCC plants cleaning coal from these seams were then selected. The feed and product coal at these plants were grab sampled and then split into various fractions. A fraction of each raw coal sample was sent to AED to be tested in the AED bench-scale separator (Tech 1). Another fraction of each raw coal sample and each product coal sample was analyzed at Versar's coal laboratory for ash, sulfur content, and heating value.

AED processed 27 coal samples, using their bench-scale coal-cleaning equipment. Samples processed included 1 sample from each of 24 plants and 3 samples from 1 plant. Analyses of the feed and product for sulfur, ash, and heating value are reported for the AED Process tests.

Because the field samples obtained were grab samples and not time-averaged, it was not feasible to conduct a detailed assessment of the performance of the AED Tech 1 Process relative to the individual PCC plants. However, a qualitative comparison was made by simply counting the number of times the Tech 1 Process performed significantly better or worse than the single samples obtained from the appropriate PCC plant. The Tech 1 Process exhibited a much better capability to remove sulfur than the coal washing plants from which the coals were obtained. The sulfur removal of the Tech 1 Process was greater for the high-to-moderate-sulfur coals than for the very-low-sulfur coals. Ash removal capability of the Tech 1 Process was shown to be lower than the ash removal capability of the conventional coal preparation plants. However, in the "fine" fraction, where ash particles are larger than 53 microns in average diameter, the Tech 1 Process removes slightly more ash than does conventional coal washing.

Cost evaluations of the PCC technology were performed using the actual process flow diagrams from six of the PCC plants visited during the sampling period. These flow diagrams were modified and process equipment was sized to provide a common basis for these designs. The results of these cost analyses were reduced to unit costs for product, based on the energy content of the grab samples and estimates of mass recovery provided by the respective plant operators. Two conceptual designs were developed for the AED Tech 1 Process: one at a minemouth (this requires briquetting the product coal) and one at an existing power plant. The unit costs for these designs lead to the conclusion that costs of coal cleaning by the Tech 1 Process are in the same range as the costs for the PCC plants examined.

System availability - ability to operate continuously for long periods of time - is statistically high for electrostatic separation systems operating in iron mining and in concentrating titanium dioxide from ore. Similar performance (i.e., 95 percent availability) is expected when this technology is applied to coal processing. As a result, it is reasonable to project at least 6000 hours of operation per year, compared with 3400 hours a year for conventional PCC plants. At a typical titania facility, the electrostatic equipment operates at least 90 percent of 24 hours per day, 7 days a week.

In conclusion, the results of this program make it clear that the AED Process deserves further study. Its superior performance on sulfur removal, adequate potential for ash removal, moderate costs, and potential for retrofit to existing coal-burning power plants all combine to make this technology an exciting possibility for inexpensive reduction of sulfur oxide emissions. There are a number of avenues of investigation which could be pursued to develop a more refined assessment of the merits of the process.

SECTION 3

RECOMMENDATIONS

The main recommendation which can be made as a result of this work is that the AED Process deserves further study. Its superior performance on sulfur removal, adequate potential for ash removal, moderate costs, and potential for retrofit to existing coal-burning power plants all combine to make this technology a possibility for dealing with sulfur oxide emissions.

Since the completion in 1981 of the coal testing which is the subject of this report, important improvements have been made in the AED coal cleaning process. Preliminary results look promising and warrant further evaluation.

There are a number of avenues of investigation which should be pursued to develop a more refined assessment of the merits of the process. These include:

- A better statistical basis for the evaluation of competing PCC processes,
- Feedstocks to the AED Process should be precleaned (to remove mined rock),
- Data on equipment life and maintenance requirements for the AED Process should be developed at a larger scale,
- Various aspects of process optimization of the AED Process should be explored at the pilot-scale level, and
- Additional feed/product analyses should be made to help to characterize the process more completely, including ash fusion temperatures, elemental analyses of coals, and parallel flood sink testing (for comparison purposes).

SECTION 4

PROGRAM DESCRIPTION

A. COAL SAMPLING AND ANALYSIS

Selection of Sampling Sites

The various activities involving the selection of sampling sites included identification and selection of coal seams, identification of PCC plants using coals from these seams, and confirmation of sampling visits with the PCC operators.

Three factors were considered for the selection of representative coal seams in the United States for cleaning purposes: coal production data, coal characteristics, and geographical distribution of coal seams. First, a review of state coal production data was conducted to identify the major coal-producing seams in various coal regions in the United States. A list of major coal seams was prepared as a result of this review. This list was then evaluated by considering the cleaning potential of selected coal seams by coal cleaning methods. High sulfur and/or ash content and/or pyritic-to-total-sulfur ratio (if data were available) of coals was used as the criterion for this screening process. Another consideration was the geographical distribution of the coal seams. A wide geographical area was covered to select coal seams with a broad range of properties.

After the selection of the coal seams, the PCC plants cleaning coal from these seams were identified. Priority was given to PCC plants cleaning exclusively one coal seam instead of a blend of various seams. Another criterion used for the selection of the PCC plants was related to the level of cleaning in PCC plants. Only the PCC plants cleaning coals beyond "Level 1" were chosen, that is, beyond crushing and screening.

After a preliminary list of PCC plants was prepared, the operators of these plants were contacted to obtain their cooperation in the sampling program. Initial contacts, which were made by telephone, were followed up by mail. A final list of the PCC plants was prepared after the cooperation of PCC plant operators had been established. This list was adopted for the sampling program.

The list of the sampling sites contains 25 PCC plants. These plants are located in all of the U.S. coal regions, except for the Western region, and span over 10 states. Five plants are located in Pennsylvania and Illinois, each; four plants in West Virginia; three plants in Kentucky; two plants in Ohio and Indiana, each; and one plant in Tennessee, Alabama, Kansas and Missouri, each. Twenty-two of the selected 25 plants clean coal originating from a single seam (i.e., they do not clean coal blended from two or more seams). Figure 1 shows the geographical distribution of the selected coal seams and the PCC plants sampled. The plant names are designated with code names and numbers and are not identified. Table 1 lists the plant codes, the coal origin (in terms of seam, state, and county), and the major equipment used in the selected PCC plants.

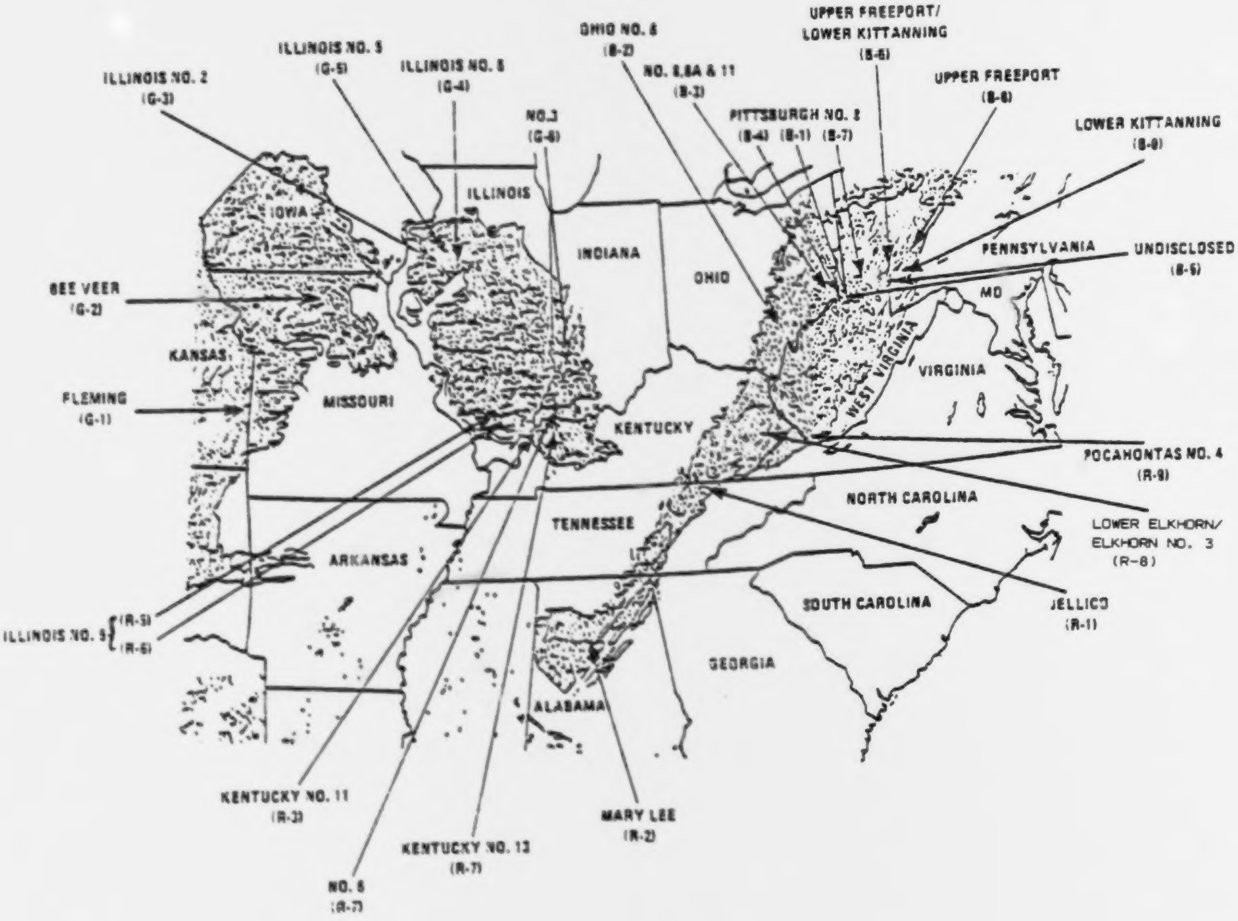

ILLINOIS NO. 2
(G-3)
ILLINOIS NO. 5
(G-5)
ILLINOIS NO. 6
(G-4)
NO.3
(G-6)
OHIO NO. 6
(B-2)
NO. 6,6A & 11
(B-3)
PITTSBURGH NO. 8
(B-4) (B-1) (B-7)
UPPER FREEPORT/
LOWER KITTANNING
(B-6)
UPPER FREEPORT
(B-8)
LOWER KITTANNING
(B-9)
UNDISCLOSED
(B-5)
BEE VEER
(G-2)
FLEMING
(G-1)
IOWA
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
MD
KANSAS
MISSOURI
KENTUCKY
WEST VIRGINIA
VIRGINIA
POCAHONTAS NO. 4
(R-9)
NORTH CAROLINA
TENNESSEE
ARKANSAS
LOWER ELKHORN/
ELKHORN NO. 3
(R-8)
SOUTH CAROLINA
JELLICO
(R-1)
ILLINOIS NO. 5 (R-5) (R-6)
GEORGIA
ALABAMA
KENTUCKY NO. 11
(R-3)
MARY LEE
(R-2)
KENTUCKY NO. 13
(R-7)
NO. 6
(R-7)

Figure 1. Geographical Distribution of the Selected Coal Seams and the PCC Plant Sampled

TABLE 1. LIST OF THE SAMPLING SITES, COAL ORIGINS, AND MAJOR PLANT EQUIPMENT

Plant Code	Seam	Coal Origin State	Coal Origin County	Major Plant Equipment J	HV	HC	TAB	CY	F
B-1	Pittsburgh No. 8	WV	Harrison		X		X	X	X
B-2	Ohio No. 6	OH	Perry	X				X	
B-3	No. 8/8a/11	OH	Belmont		X	X		X	
B-4	Pittsburgh No. 8	WV	Marshall		X	X		X	X
B-5	Undisclosed	PA	Green	X					
B-6	Upper Freeport/ Lower Kittanning	PA	Armstrong	X				X	X
B-7	Pittsburgh No. 8	PA	Allegheny	X	X		X	X	X
B-8	Upper Freeport	PA	Indiana			X	X	X	
B-9	Lower Kittanning	PA	Somerset			X		X	
R-1	Jellico	TN	Clairborne		X		X	X	
R-2	Mary Lee	AL	Jefferson		X		X	X	
R-3	Kentucky No. 11	KY	Union	X				X	
R-4	Kentucky No. 13	KY	Ohio	X				X	
R-5	Illinois No. 6	IL	Franklin		X			X	
R-6	Illinois No. 6	IL	Williamson	X				X	X
R-7	No. 6	IN	Warrick	X				X	X
R-8	Lower Elkhorn/ Elkhorn No. 3	KY	Pike	X	X			X	
R-9	Pocahontas No. 4	WV	Mercer		X	X			X
G-1	Fleming	KS	Bourbon	X					
G-2	Bee Veer	MO	Randolph	X				X	
G-3	Illinois No. 2	IL	Fulton		X	X			
G-4	Illinois No. 6	IL	Peoria	X				X	
G-5	Illinois No. 5	IL	Knox	X				X	
G-6	No. 3	IN	Clay	X				X	
S-1	Lower Kittanning	WV	Barbour		X		X		X

J: Jig
HV: Heavy media vessel
HC: Heavy media cyclone
TAB: Concentrating table
CY: Cyclone
F: Flotation

Sample Collection Program

Coal sampling was conducted at 25 coal preparation plants. Grab samples were collected for both the feed and clean coal at these plants and stored in sealed plastic jugs. Table 2 shows the sampling locations for each sample collected as well as the sampling methods and approximate sample weights.

Feed coal sample collection locations at 25 coal preparation plants included raw coal stockpiles, raw coal belt conveyors to the plant, outfall of the raw coal feed belt to storage silos, and outfalls of the feed storage silo to the feed conveyor belt. Overall plant clean coal samples were collected from either one of these three sampling locations: product belt conveyor, outfall of the product belt conveyor (to trains, trucks, barges or storage silos), and product storage silos.

Because of time and funding limitations, it was not possible to take a large number of time-sequenced samples at each sampling location in order to assess the variability of the properties of the raw coal and product coal. Since raw coal properties have repeatedly been shown to vary dramatically with time, due to the inhomogeneity of the coal seam itself, great caution must be observed in using the feed and product sample data to estimate plant performance. The feed and product coal samples may come from different portions of the coal seam and may exhibit quite different properties (ash and sulfur) even when the effects of washing are taken into account (i.e., the feed and product samples may not be truly matched in that each may be representative of a different portion or location in the coal mine).

The sample collection methods used in this program included stopped-belt cut, full-stream cut, part-stream cut, and stationary coal sampling. These individual sample collection methods were conducted in accordance with ASTM Standard D2234 and are described as follows:

- Stopped-Belt Cut - A loaded conveyor belt is stopped and a full cross-section cut with parallel sides is removed from the coal streams.
- Full Stream Cut - A full cross-section cut is removed from a moving stream of coal.
- Part-Stream Cut - A portion, not a full cross-section, is removed from a moving stream of coal.
- Stationary Coal Sampling - A portion of coal is collected from a pile, a rail car, or a barge.

The type of samplers used in the coal sampling program include the shovel, automatic and manual samplers, and a hand-held sampler. Stopped belt cuts, part-stream cuts, and stationary coal samples were collected with a shovel. Full-stream cuts were collected by a primary cutter of an automatic sampler and with manual samplers, and part-stream cuts were collected with a hand-held sampler.

TABLE 2. SAMPLING PROCEDURE

Plant	Seam	Sample	Sampling Location	Sampler Type	Sampling Method	Approximate Grab Sample Weight kg	Approximate Grab Sample Weight lbs
B-1	Pittsburgh #8	Plant Feed	Conveyor Belt to Raw Coal Screens	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Plant Product Conveyor Belt	Automatic Sampler	Full-Stream Cut	23	50
B-2	Ohio #6	Plant Feed	Stockpile Conveyor Belt to Rotary Breaker	Shovel	Stopped-Belt Cut	91	200
B-3	8/8a/11	Plant Feed	Conveyor Belt to Rotary Breaker	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Conveyor Belt to Clean Coal Automatic Sampler	Shovel	Part-Stream Cut	23	50
	# 11	Truck Sample	Coal Pile at Truck Weigh-In site	Shovel	Stationary Coal Sample	45	100
B-4	Pittsburgh #8	Plant Feed	Conveyor Belt to Rotary Breaker	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Conveyor Belt between Automatic Sampler and Barge Loading Chute	Shovel	Stopped-Belt Cut	23	50
B-5	Undisclosed	Plant Feed	Conveyor Belt to Plant	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Conveyor Belt to Barge	Shovel	Stopped-Belt Cut	23	50
B-6	Upper Freeport	Plant Feed	Outfall from Conveyor Belt to Raw Coal Silo from the Mine	Shovel	Part-Stream Cut	91	200
		Plant Product	Product Conveyor Belt Outfalls	Manual Sampler	Full-Stream Cut	23	50
	Lower Kittanning	Plant Feed	Outfall from Storage Silo to Plant Conveyor Belt	Shovel	Part-Stream Cut	91	200
		Plant Product	Product Conveyor Belt Outfall	Manual Sampler	Full-Stream Cut	23	50
B-7	Pittsburgh #8	Plant Feed	Conveyor Belt to Plant	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Conveyor Belt to Train Loading Hopper	Hand-Held Sampler	Part-Stream Cut	23	50
B-8	Upper Freeport	Plant Feed	Feed Conveyor Belt	Automatic Sampler	Full-Stream Cut	91	200
		Plant Feed	Feed Conveyor Belt	Automatic Sampler	Full-Stream Cut	91	200

(cont.)

TABLE 2. (CONT)

Plant	Seam	Sample	Sampling Location	Sampler Type	Sampling Method	Approximate Grab Sample Weight kg	Approximate Grab Sample Weight lbs
R-9	Lower Kittanning	Plant Feed	Feed Conveyor Belt	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Conveyor Belt	Automatic Sampler	Full-Stream Cut	23	50
R-1	Jellico	Plant Feed	Feed Conveyor Belt	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Conveyor Belt Outfall	Manual Sampler	Full-Stream Cut	23	50
R-2	Mary Lee	Plant Feed	Feed Conveyor Belt	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Train Car Loading Chute	Shovel	Full-Stream Cut	23	50
R-3	Kentucky #11	Plant Feed	Feed Conveyor Belt	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Storage Pile	Shovel	Stat. Coal Sample	23	50
R-4	Kentucky #13	Plant Feed	Feed Conveyor Belt	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Conveyor Belt	Automatic Sampler	Full-Stream Cut	23	50
R-5	Illinois #6	Plant Feed	Feed Conveyor Belt	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Storage Pile	Shovel	Stat. Coal Sample	23	50
R-6	Illinois #6	Plant Feed	Feed Conveyor Belt	Automatic Sampler	Full-Stream Cut	91	200
		Plant Product	Product Conveyor Belt	Automatic Sampler	Full-Stream Cut	23	50
R-7	Indiana #6	Plant Feed	Feed Conveyor Belt	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Conveyor Belt	Automatic Sampler	Full-Stream Cut	23	50
R-8	Lower Elkhorn, Elkhorn #3	Plant Feed	Feed Conveyor Belt	Automatic Sampler	Full-Stream Cut	91	200
		Plant Product	Product Conveyor Belt	Automatic Sampler	Full-Stream Cut	23	50
R-9	Pocahontas #4	Plant Feed	Feed Conveyor Belt	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Conveyor Belt	Shovel	Stat. Coal Sample	23	50

(cont.)

TABLE 2. (CONT)

Plant	Seam	Sample	Sampling Location	Sampler Type	Sampling Method	Approximate Grab Sample Weight kg	Approximate Grab Sample Weight lbs
G-1	Fleming (Baxter)	Plant Feed	Feed Storage Pile	Shovel	Stat. Coal Sample	91	200
		Plant Product	Product Storage Pile	Shovel	Stat. Coal Sample	23	50
G-2	Bee Veer	Plant Feed	Feed Storage Pile	Shovel	Stat. Coal Sample	91	200
G-3	Illinois #2	Plant Feed	Feed Conveyor Belt	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Conveyor Belt	Automatic Sampler	Full-Stream Cut	23	50
G-4	Illinois #6	Plant Feed	Feed Storage Pile	Shovel	Stat. Coal Sample	91	200
		Plant Product	Product Storage Pile	Shovel	Stat. Coal Sample	23	50
G-5	Illinois #5	Plant Feed	Feed Conveyor Belt	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Storage Pile	Shovel	Stat. Coal Sample	23	50
B-6	No. 3	Plant Feed	Feed Conveyor Belt	Shovel	Stopped-Belt Cut	91	200
		Plant Product	Product Conveyor Belt	Automatic Sampler	Full-Stream Cut	23	50
S-1	Lower Kittanning	Plant Feed	Feed Conveyor Belt	Automatic Sampler	Full-Stream Cut	91	200
		Plant Product	Product Conveyor Belt	Automatic Sampler	Full-Stream Cut	9	20

All but three of the plants process coal originating from a single seam. These three plants are indicated in this study with the code numbers B-3, B-6, and R-8. At plant B-3, the feed coal to the process on the sampling day was a blend of Ohio No. 8, 8a, and 11 seams. A sample of this mixture was collected from the raw coal belt conveyor. In addition, a truck sample was obtained containing exclusively No. 11 coal. However, there was no corresponding clean coal available for the No. 11 coal.

In Plant B-6, the feed coal consisted of 76 percent (by weight) Upper Freeport seam and 24 percent Lower Kittanning seam. These coal seams were introduced to the process simultaneously by two separate belt conveyors. Samples of these coal seams were collected from each belt conveyor. The plant products consisted of metallurgical grade coal (48 percent of the product stream) and middlings (52 percent of the product stream). Samples of each product stream were take from their respective belt conveyors.

The feed to Plant R-8 consisted of a blend of Lower Elkhorn and Elkhorn No. 3 seams. Samples of this raw coal were collected from the plant feed belt conveyors.

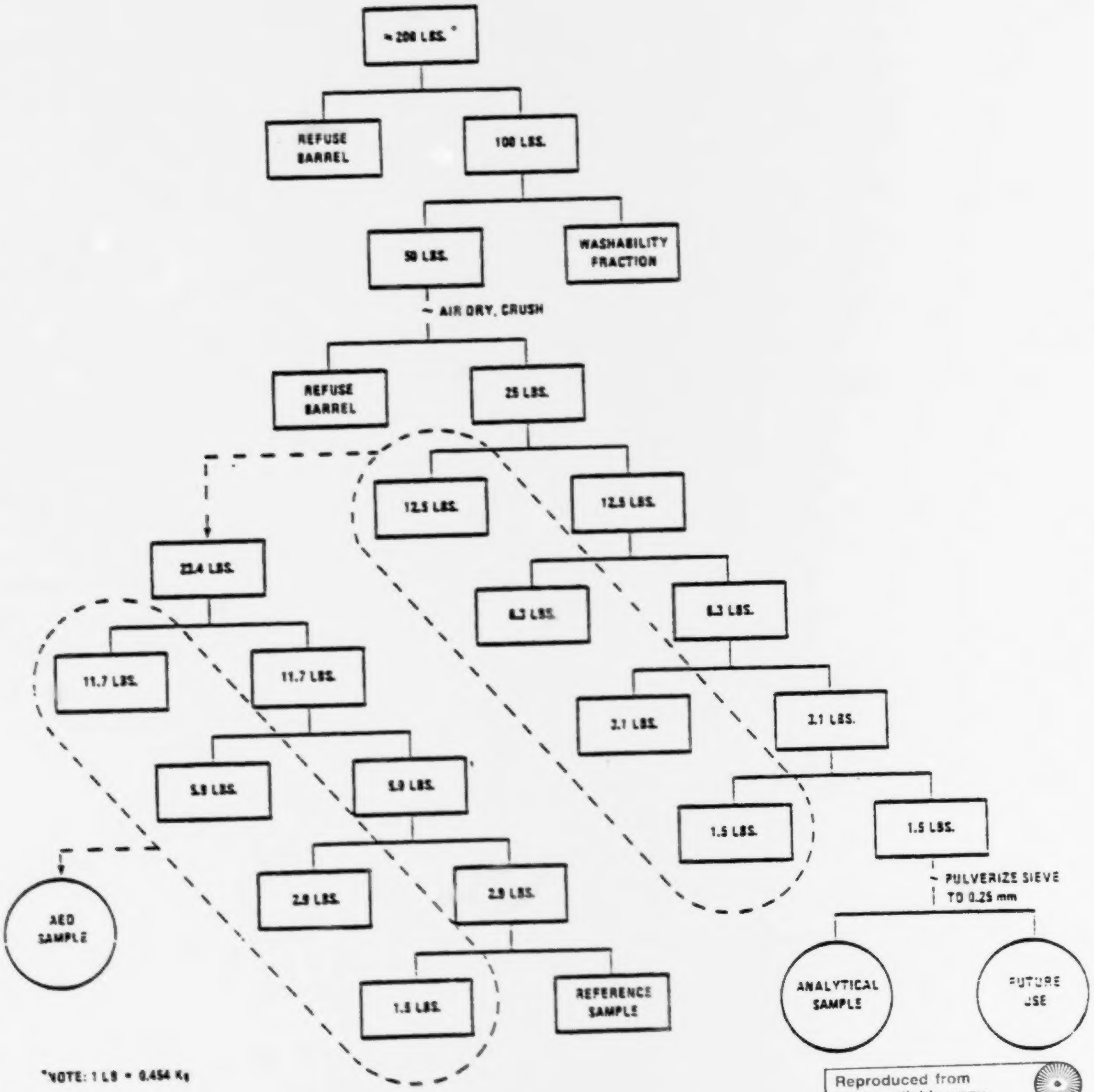
The feed to Plant B-8 was from a single seam (Upper Freeport), but it originated from two different mines. Coal from each mine was introduced to the process by a separate belt conveyor. A sample from each conveyor was obtained at this plant. Since the plant was not operating on the sampling day, the clean coal sample could not be collected.

At Plants B-2 and G-2, clean coal samples were not obtained. However, the raw coal samples were obtained from the feed belt conveyor and the feed storage pile, respectively.

The coal samples collected were reduced to quantities appropriate to various sample functions by the procedures illustrated in Figures 2 and 3. Sample volume reduction was based on the ASTM Procedure D2013, "Preparing Coal Samples for Analyses."

The feed coal samples were first reduced by the cone and quarter method to approximately two 22.7 kg (50 lb) fractions. One fraction was sealed in an air-tight bag for future analyses if needed. The second fraction was air-dried, crushed by a jaw crusher, and riffled in a Gilson splitter into two approximately 11.4 kg (25 lb) fractions. One fraction was placed in the coal refuse barrel and the second fraction was then riffled to produce a representative analytical sample. Concurrent with the analytical sample preparation, reject portions of the splits were combined and then riffled to produce a reference sample, which was representative of the sample shipped to AED. The reject fractions of these splits were combined to produce the coal sample shipped to AED.

The analytical samples were reduced to minus 60 mesh using a Holmes Model 500 pulverizer. This material was split into two fractions and sealed in separate containers. One sample was used for immediate coal analysis and the other sample was for future use. Figure 2 illustrates the sample volume reduction for the feed coal.


≈ 200 LBS. *
REFUSE BARREL
100 LBS.
50 LBS.
WASHABILITY FRACTION
AIR DRY, CRUSH
REFUSE BARREL
25 LBS.
12.5 LBS.
12.5 LBS.
23.4 LBS.
6.3 LBS.
6.3 LBS.
11.7 LBS.
11.7 LBS.
3.1 LBS.
3.1 LBS.
5.9 LBS.
5.9 LBS.
1.5 LBS.
1.5 LBS.
PULVERIZE SIEVE TO 0.25 mm
AED SAMPLE
2.9 LBS.
2.9 LBS.
ANALYTICAL SAMPLE
FUTURE USE
1.5 LBS.
REFERENCE SAMPLE

*NOTE: 1 LB = 0.454 Kg

Reproduced from best available copy.

Figure 2. Feed Sample Volume Reduction and Preparation

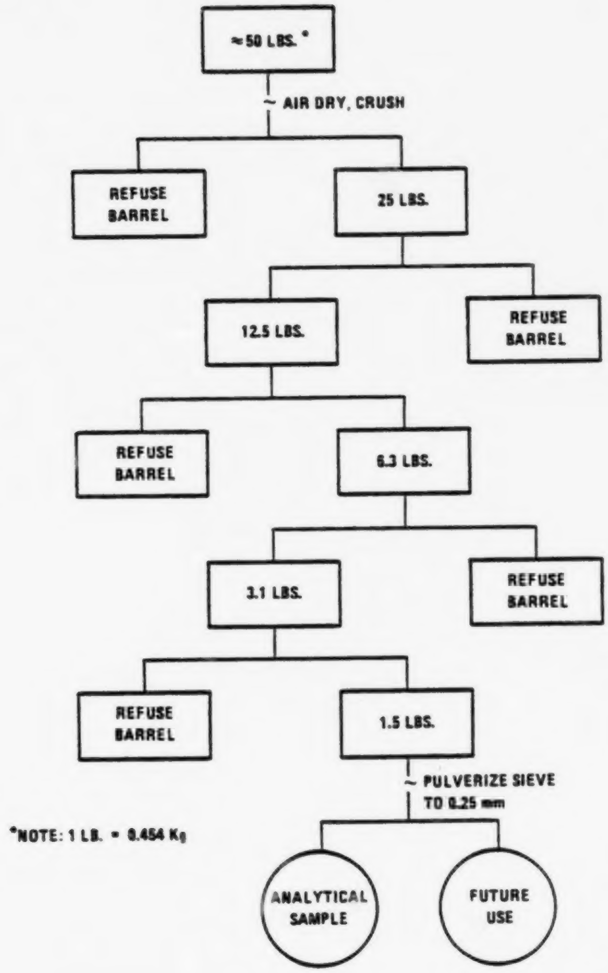

≈ 50 LBS. *
~ AIR DRY, CRUSH
REFUSE BARREL
25 LBS.
12.5 LBS.
REFUSE BARREL
REFUSE BARREL
6.3 LBS.
3.1 LBS.
REFUSE BARREL
REFUSE BARREL
1.5 LBS.
~ PULVERIZE SIEVE TO 0.25 mm
*NOTE: 1 LB. = 0.454 Kg
ANALYTICAL SAMPLE
FUTURE USE

Figure 3. Clean Coal Sample Volume Reduction and Preparation

The sample volume reduction procedure followed in this project is shown in Figure 3. Since the clean coal samples were smaller in volume than the raw coal sample, they were first air dried and crushed to 6.4 mm (0.25 in.) top size. Each crushed sample was then riffled to approximately 0.7 kg (1.5 lb). This fraction was pulverized to minus 250 microns (60 mesh) and split into two fractions. These two fractions were sealed in separate containers; one for immediate coal analyses and the other for future use. All the reject fractions from the product coal reduction process were combined in the refuse container.

Handling and Analysis of Samples Obtained at PCC Plants

All the feed and clean coal samples were analyzed for moisture, ash, heat content, pyritic sulfur, and total sulfur. The analytical methods used are listed in Table 3. Detailed procedures and results of the analyses are presented in Appendix A.

TABLE 3. ANALYTICAL TEST METHODS

Test	Reference	Comment
Moisture	ASTM 3302-74	Air-dry loss and residual moisture. Total moisture by calculation.
Ash	ASTM 3174-73	
Heat Content	ASTM 2015-77	
Pyritic Sulfur	ASTM D 2492-79	Atomic absorption. Method for iron determination.
Total Sulfur	ASTM D 3177-75	Leco High Frequency Combustion Titration Test

To ensure that the coal analyses data were precise, a quality control program was followed. All the samples were analyzed in duplicate and the data were recorded on a master form. The data were then entered into a programmable calculator which then calculated the results on an as-received basis, dry weight basis, and dry ash-free basis. The acceptability of duplicate analyses were based upon precision criteria for repeatability established for the individual test methods. Comparisons of duplicates were made using these criteria and samples were re-analyzed as necessary.

B. PROCESSING BY THE AED BENCH-SCALE SYSTEM

Potential Advantages - The AED Process is Based on Two Central Principles:

a) When properly handled, the differences in resistivity between inorganic impurities in pulverized coal and their largely organic counterparts are substantial (several to ten orders of magnitude), and

b) The inorganic matter (whether sulfur or ash) in the coal matrix is, generally, not chemically bound to the coal and can be freed for separation by adequate comminution. This is particularly pertinent with regard to sulfur-containing materials. Greer ([3]) reports that pyrite exists in three basic forms in run-of-mine (ROM) coal. These are: 1) monocrystals, from 1-5 microns in effective diameter; 2) aggregates of these monocrystals, termed framboids, running from 20-50 microns in effective diameter; and 3) larger particles of pyrite which have been pulverized along with the coal (termed secondary pyrite). Conventional coal cleaning - without pulverization - has access only to the third category mentioned above, secondary pyrite. The other forms of pyrite, both monocrystals and framboids, are not accessible to conventional coal cleaning because these materials are encapsulated within the organic coal structure. Although generally accepted in the industry, this latter point has not been utilized in physical coal cleaning processes, because of the inefficiency and cost of separating fine particles in conventional coal and mineral preparation equipment.

In the AED Process these two principles can be combined synergistically and without excessive cost. In simplest terms, coal is pulverized, size fractionated, given a mild electrostatic charge after being fed to the surface of a rotating cylinder of opposite polarity (See Figure 4). Care must be taken to strike the proper balance between electrostatic and mechanical forces in determining voltage and rotation speed. After charging, the more conductive inorganic matter soon loses its charge and flies off the cylinder due to centrifugal force, leaving a coal-enriched material to be removed with a separator (doctor) blade.

As the particle size of the coal becomes very small, boundary layer problems and interparticle forces interfere with the charging/discharging process, reducing its efficiency. For this reason, particles smaller than approximately 20 microns were not processed in the Tech 1 bench-scale separator used in this study.

Control Alternatives/Process Configurations

The AED Process has the capability (not explored in this study) of being operated at varying recovery levels by changing the corona voltage and rotation rate. This enables the operator to optimize sulfur-ash removal and energy recovery for a given coal, taking temporal variability of the coal into account, or when changing to another coal seam. Furthermore, it is

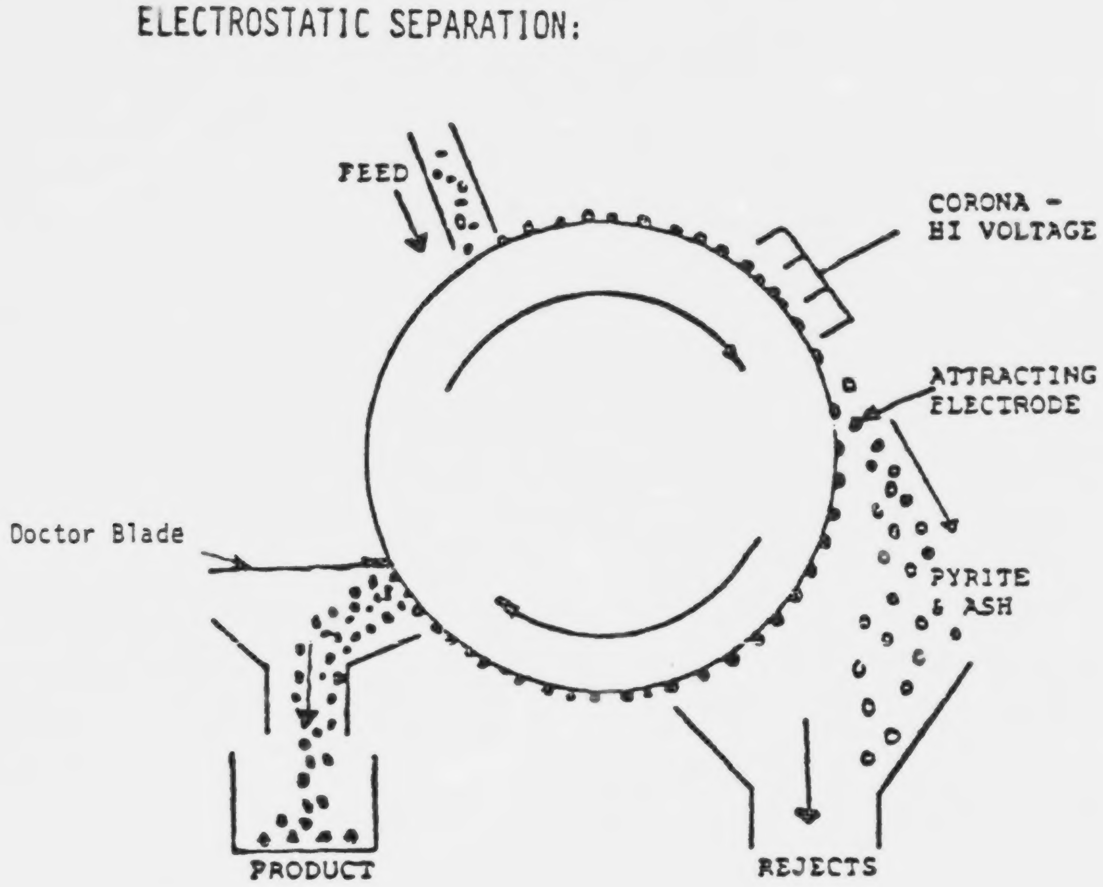

ELECTROSTATIC SEPARATION:
FEED
CORONA -
HI VOLTAGE
ATTRACTING
ELECTRODE
Doctor Blade
PYRITE
& ASH
PRODUCT
REJECTS

Figure 4. Diagram of the Operation of the AED Process Roll-Separator

possible to recycle either waste or product through another AED Process separator, if such processing further optimizes the result. In the results described below (and the succeeding economic analyses) some of the materials are run through two successive electrostatic separators. In some cases, precleaning by conventional coarse coal preparation techniques and a single round of electrostatic processing would be optimal while in others an additional (third) step might be warranted. All of these aspects of the AED Process are beyond the scope of this study; however, they deserve mention here because the controllable aspects of the electrostatic separation can be used to optimize the separation process.

Description of the Bench-Scale System

The AED Tech 1 Process scheme used in this project is best understood by reference to Figures 4 and 5. ROM coal was pulverized with a hammermill to pulverized coal ("p.c.") size (60 to 80 percent minus 200 mesh). After pulverization, the moisture content of the coal was adjusted by either (drying or humidifying) or (heating and dehumidification) so that there was 2 to 4 percent total moisture in the pulverized coal. This is within the range of the moisture content normally experienced in the output of pulverizers associated with industrial and electric power utility boilers.

After moisture content adjustment, the coal was air classified in two stages. The first stage used an air classifier whose overflow primarily contained "ultrafine" particles (minus 20 microns). These particles were not processed in any way, but were added to the products of the coal cleaning circuits. The underflow of the 20-micron air classifier was taken to a second air classifier that produced two ranges of particle sizes - fine and very fine. The "fine" particles (246 x 53 microns) and very fine (53 x 20 microns) were sequentially cleaned in a Tech 1 bench-scale roll separator. The rotation speed and other separator variables were appropriately adjusted for the fine or very fine particle size ranges. After processing, the rejects of each separation were processed again (recycled) in order to recover additional coal, thereby increasing the energy recovery of the system.

All coals were run as shown in Figure 5. The first products were taken immediately to the final product stream as shown. Middlings and rejects were rerun, resulting in 12 second-run output streams. All rejects were then sent to the system rejects output. The products and middlings - 8 in all - were switched either to final products or final rejects, depending on the results measured for each such output. This process were adjusted to optimize overall performance for each coal.

The overall results are shown in Appendix B for each coal tested. The process diagrams are simplified, listing the salient intermediate data and the final results. Twenty-six sets of measurements were made for each coal tested. Each set of measurements included percent sulfur, percent ash, weight percent, and Btu per pound. From these data, all other values were calculated.

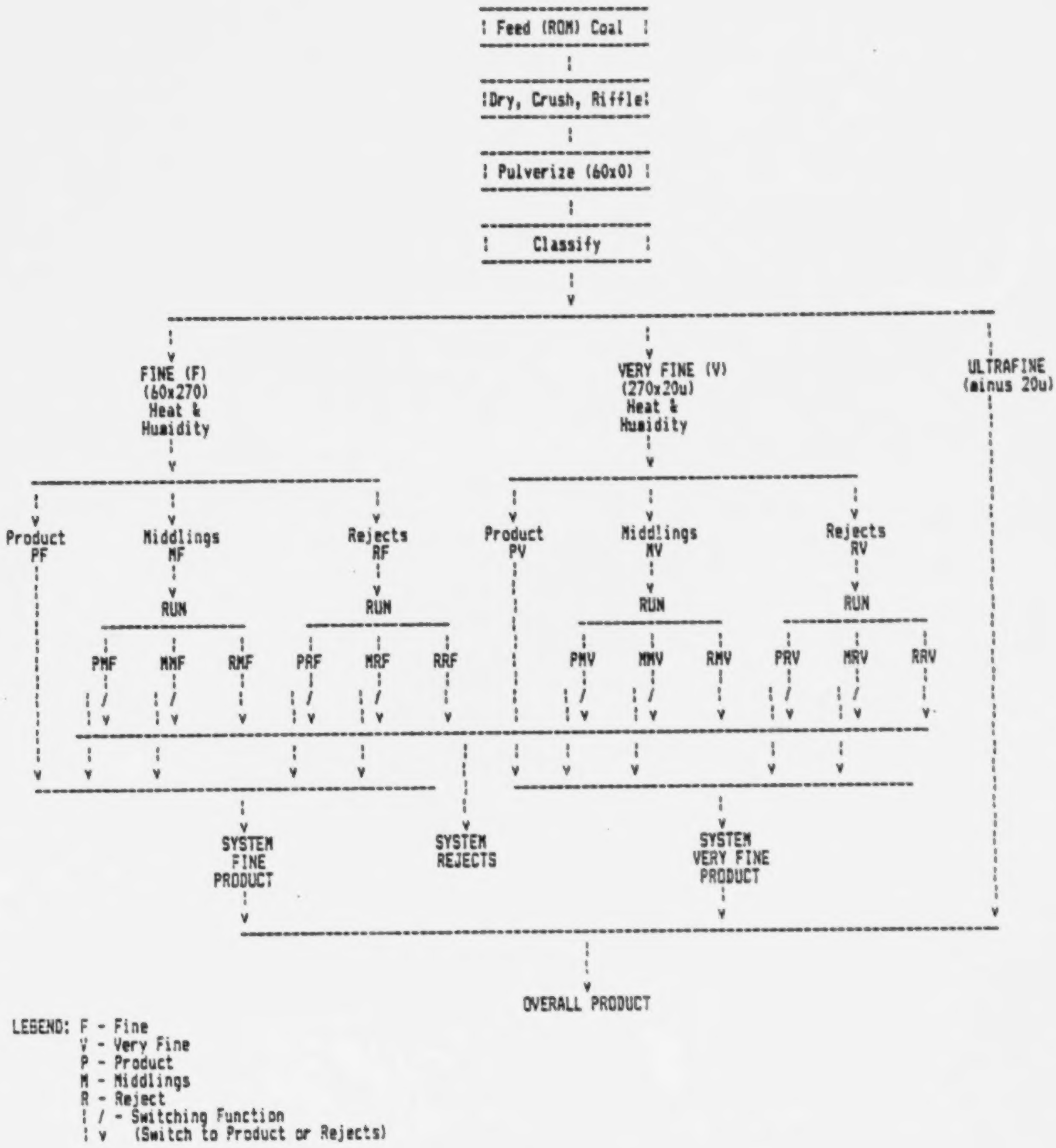

Feed (ROM) Coal
Dry, Crush, Riffle
Pulverize (60x0)
Classify
FINE (F)
(60x270)
Heat &
Humidity
VERY FINE (V)
(270x20u)
Heat &
Humidity
ULTRAFINE
(minus 20u)
Product
PF
Middlings
MF
Rejects
RF
Product
PV
Middlings
MV
Rejects
RV
RUN
RUN
RUN
RUN
PMF
MMF
RMF
PRF
MRF
RRF
PMV
MMV
RMV
PRV
MRV
RRV
SYSTEM
FINE
PRODUCT
SYSTEM
REJECTS
SYSTEM
VERY FINE
PRODUCT
OVERALL PRODUCT
LEGEND: F - Fine
V - Very Fine
P - Product
M - Middlings
R - Reject
¦ / - Switching Function
¦ v (Switch to Product or Rejects)

Figure 5. Schematic Flow Diagram of AED Coal Processing Procedures

Procedures and Instrumentation

All coals were tested in the AED Tech 1 unit under the same conditions; the corona voltage and drum rotation rate were identical for the same particle size range (i.e., fine, very fine, ultrafine) of each coal tested. This undoubtedly resulted in less than optimum performance for a given coal.

Moisture was not measured on any of the raw coal samples. However, all of the coal was air dried (during a New England winter) and kept in sealed plastic containers prior to analysis. Thus, all coal analyses are reported on that air-dried basis.

The following procedure describes how the coal was handled and processed from as-received samples to final analysis and data reduction.

The ROM coal samples were stored in their original containers until ready for use. Each entire sample was set out on a hard plastic laminate-topped table and allowed to air dry overnight. The next day it was crushed and a sample of about 2500 grams (5.5 lb) was riffled thoroughly. The sample was weighed and then pulverized at slow speed in an air-swept hammermill with an internal screen of 250 micron (60 mesh). The 250 micron x 0 (60 mesh x 0) pulverized coal was collected in a cyclone, weighed and a sample taken for analysis.

The two fractions processed on the AED separator were: the fine fraction, 250 x 53 micron (60 x 270 mesh); the very fine fraction 53 x 20 micron; and the ultrafine fraction, 20 x 0 micron. The two fractions were processed independently in the separator. Each sample was weighed and the separator was prepared for the particle size range being run. The two fractions were run under different conditions due to the requirements of particle size on the balance of electrostatic and mechanical forces. The moisture content was adjusted before processing.

As shown schematically in Figure 5, each sample was run through an ionizer, then into a feeder and distributed onto a rotating drum under high voltage corona wires (20,000 volts). Three fractions were collected: rejects, middling, and product. The rejects and middlings were weighed, sampled, and then rerun under the same conditions as the original run, but without additional heating or humidifying. The various product streams from the fine runs were combined into a fine coal product and the very-fine run products were combined into a very-fine coal product. The fine and very-fine coal products were weighed and samples were taken for analysis. The coarse and very-fine coal products were combined with the ultra-fine coal to form an overall product and weighed (See Figure 5). The overall product was weighed and samples were taken for analysis.

Each sample was weighed and then analyzed for sulfur, ash, and energy content. A few of the high ash reject samples were not analyzed for energy content because of the difficulty in obtaining complete combustion of a low energy content material in the Parr Calorimeter. The sulfur analysis was done on a Fisher automatic sulfur analyzer (Model 475). This instrument measures sulfur content by high temperature combustion of the sample in oxygen at 1350°C (2460°F) in the presence of a vanadium pentoxide flux and catalyst. The products of combustion are scrubbed in an organic liquid, after which the SO_2 captured in the liquid is automatically titrated with a standard iodine solution, using an electrical conductivity end point. Two sulfur measurements were taken on each sample and the results averaged. This instrument was calibrated two times each day with 2.5 percent sulfur standards furnished by Fisher Scientific. Ash content was measured in accordance with ASTM 3174-73: a weighed sample of coal is combined in air in a muffle furnace at 750°C (1380°F) and the residue is weighed. Energy content was measured using a Parr bomb calorimeter.

Quality Assurance

The quality assurance approach utilized involved a multiplicity of internal consistency checks on the data, rather than conducting duplicate analyses. After each coal was analyzed, "balances" were drawn on sulfur, ash, energy and yield by weight to check for discrepancies or errors that might have occurred during the analysis. If the balances were more than five percent in error, the samples were rerun. These balances were obtained for the classification results, and for each run on the separator, including the recycling of the "rejects" and "middlings".

C. ECONOMIC ANALYSES

Comparison of the economics of the AED Tech 1 Process with those of typical PCC plants now in operation. This was done by developing conceptual designs and economic analyses for 6 of the 25 coal preparation plants visited during the coal sampling portion of this project. This work was done by Versar, Inc. In addition, Stone & Webster Engineering Corporation and AED collaborated to produce conceptual designs and the associated economic analyses for two process concepts involving the AED Tech 1 Process. One concept involves minemouth coal cleaning while the second deals with coal benefication at a typical existing power plant.

The details of all this work are presented in Appendices C & D, but an overview of the design concepts and results of the cost analysis are presented in Section 6 of this report. The final portion of the Section discusses the economic comparisons which can be drawn from the work. The economic analyses are presented in mid-1978 (July 1978) dollars. These estimates can be approximated to mid-1985 dollars by multiplying all numbers by 1.53 (based on Implicit Price Deflator for GNP).

The casual reader is cautioned that the designs and evaluation contain significant elements of engineering judgement which are not always explicitly justified. For example, the economic analysis conducted by Versar is based on an assumed operating factor of 3,325 hours per year for the PCC facility, whereas the AED/Stone & Webster figures assume 6,000 hours per year for the AED Tech 1 Process when operated at a coal mine or power plant. This latter assumption might seem imprudent, but actually it is more than justified by available data on roll separators processing abrasive materials (^{4}).

SECTION 5

RESULTS AND EVALUATION

A. OVERVIEW

This section of the report presents the results of tests made to characterize field samples secured from 25 PCC facilities, and also the results of processing these samples as described previously (Section 4B) on the AED bench-scale fine coal beneficiation unit at a feed rate of 125 kg/hr (275 lb/hr). The variables measured were: ash content (wt %), total sulfur content (wt %), and heating value (Btu/lb). A final parameter, process energy recovery, was calculated from the available information, although it was not measured directly. In addition to presenting the results of processing by AED for the total sample (amalgamating fine, very fine and ultrafine components), results obtained on the fine component alone are presented and discussed. An evaluation of the test results for the three size categories points to the need to improve the capability of this process to clean the very fine and ultrafine fractions.

For all of the field tests at PCC facilities, instantaneous (as opposed to time-averaged) samples of both ROM feed and process product were secured. The results of tests to characterize these coal samples are presented and discussed. Although these results are generally consistent with published data on PCC plant performance, they do not provide a basis for quantitative analysis of the PCC plant results or for quantitative comparison of PCC and the AED Tech 1 Process results, because of the field sampling method employed.

A qualitative comparison of the results from the PCC plants and of the corresponding AED Tech 1 Process results has been conducted and is presented below. Overall, this analysis indicates that the AED Tech 1 Process exhibits superior sulfur removal, equivalent energy recovery and inferior ash removal. An additional analysis of the fine size fraction component alone shows superior sulfur removal and equivalent ash reduction, as compared to the PCC plants.

Preliminary data are presented which suggest the possibility of improvement in AED Tech 1 Process results when process operating conditions are optimized. Also, test data on a pre-cleaned coal processed on the Tech 1 unit is presented. These results suggest that improved ash removal performance (vs PCC plant) can be obtained if pre-cleaning is employed. Finally, preliminary test results are presented incorporating a modification of the AED fine coal cleaning technology to make it capable of processing the ultrafine size fraction. As expected, these results promise substantially improved performance relative to what is reported in this study for the size-limited AED system.

B. RESULTS AND EVALUATION OF AED BENCH-SCALE TESTS

The processing of ROM coal samples by AED on the Tech 1 unit was conducted according to protocols described previously (Section 4.B.). The coal feed rate to the Tech 1 unit was 125 kg/hr (275 lb/hr) at each separation step in the process. The data generated during processing are presented in detail in Appendix B. An example for a single feed is presented in Figure 6. Note that the results reported for the "Total Products" stream are measured results, not calculated by material balance.

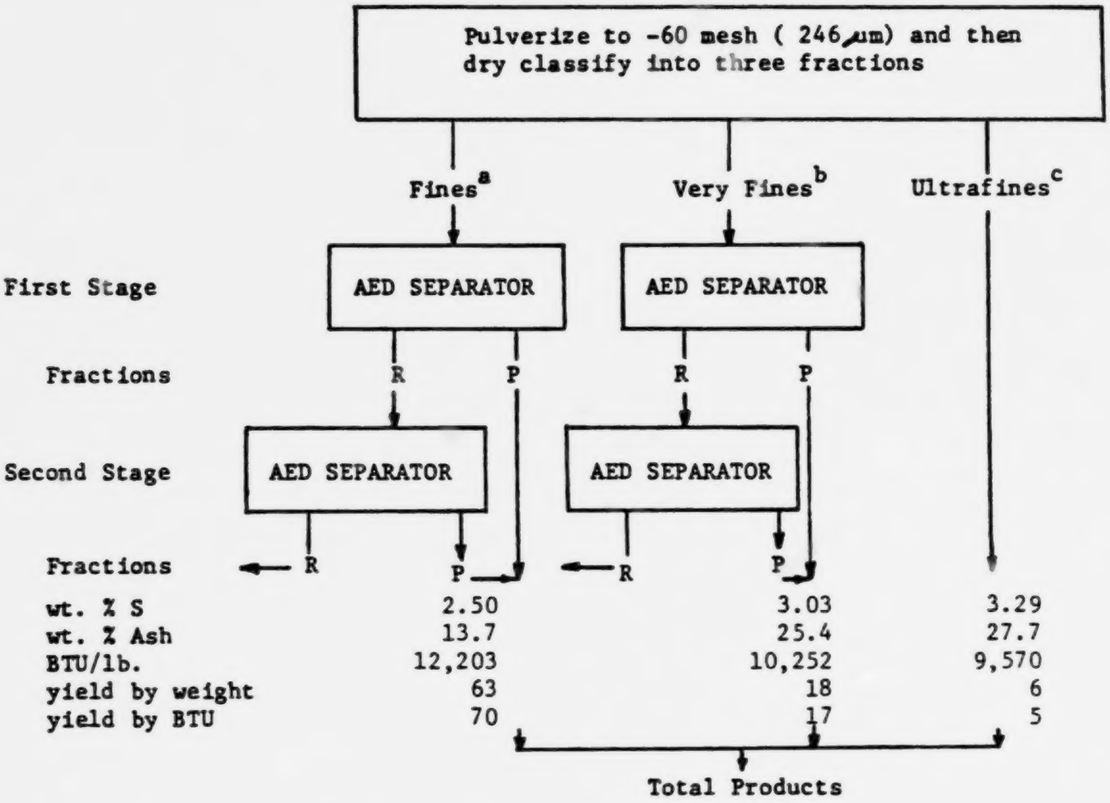
A brief study of Figure 6 will be instructive, as it is typical of the results obtained on the AED Tech 1 unit. Note that the fine fraction 246 x 53 microns represents most (63/87 ths) of the product obtained. It also receives substantial beneficiation from the processing, reducing sulfur and ash by roughly one-third over the feed. Note, also, that ash is apparently either pulverized preferentially compared to organic matter or is present in the feed in ultrafine form (or some of both). The ultrafine fraction (minus 20 microns) has roughly 40 percent more ash than the feedstock. The same trend is apparent in the ash content of the very fine fraction (53 x 20 microns), although less pronounced. Hence, we can see that significant quantities of the inorganic material are able to by-pass electrostatic separation to the detriment of the total product. It is clear that, overall, the process would be improved if it were possible to do an effective job of cleaning the ultrafine and very fine fractions.

Tables 4, 5, and 6 present summary results of processing the ROM coal samples on the Tech 1 unit described above (see Figure 5). Table 4 presents measurements made on the ROM feedstock to the process. Values reported are: Ash content (wt.%), sulfur content (wt.%) and heat content (Btu/lb). Test data reported in Table 5 are: total product and (wt.%), total product sulfur (wt.%), total product heat content (Btu/lb), weight recovery (%) and calculated total energy recovery (%), for the total process product (combined fine, very fine and ultrafine streams). Table 6 presents the same data set for the fine product alone as an aid to the comparative evaluation presented in Section D. Note that the results presented in Tables 5 and 6 confirm the above discussion of Figure 6. In general, the process does a better job of removing sulfur and ash from the fine fraction than from the combined process streams. The substantial differences in product quality are the result of inherent differences in the various coals tested.

C. RESULTS AND EVALUATION OF PCC PLANT SAMPLES

Field samples were collected according to the methodology described previously (Section 4.A.) and were analyzed by Versar, Inc., at their laboratories. Table 7 summarizes these results, which are presented in more detail in Appendix A (Table A-1). Reported are: ash content (wt.%), total sulfur (wt.%), and heat content (Btu/lb). Estimated weight recovery information provided by plant operators is also shown. Description of sampling locations, coal seams and other pertinent information is presented in Section 4.A.

wt. % S	3.49
wt. % Ash	19.5
BTU/lb	11,084


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Total Products

Fractions	Fines P	Very Fines P	Ultrafines
wt. % S	2.50	3.03	3.29
wt. % Ash	13.7	25.4	27.7
BTU/lb.	12,203	10,252	9,570
yield by weight	63	18	6
yield by BTU	70	17	5

Total Products

wt. % S	2.66
wt. % Ash	17.0
BTU/lb.	11,616
yield by weight	87
yield by BTU	92

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

NOTE: R = Rejects
P = Products

Figure 6. AED System Results, Two Stages (Coal: B-3)

TABLE 4. PROPERTIES OF FEEDSTOCK (ROM COAL) TO AED BENCH-SCALE FINE COAL PROCESSING UNIT

VERSAR SAMPLE DESIGNATION	ASH CONTENT* (wt.%)	SULFUR CONTENT* (wt. %)	HEAT CONTENT* (BTU/lb.)
B-1	14.4	3.93	12,600
B-2	22.6	2.70	10,250
B-3(8/11)	19.5	3.49	11,080
B-3(11)	20.0	2.21	11,130
B-4	38.7	4.02	8,070
B-5	32.0	2.24	10,010
B-6 (UF)	26.0	1.47	10,830
B-6 (LK)	23.1	3.99	11,540
B-6 (MIX)	-	-	-
B-7	27.8	1.96	10,710
B-8 (H)	31.5	4.04	10,170
B-8 (V)	24.8	1.84	11,290
B-9	30.0	1.79	10,340
R-1	34.1	0.86	9,210
R-2	34.4	0.96	9,290
R-3	31.0	3.74	8,870
R-4	18.9	1.42	10,510
R-5	23.3	0.83	10,110
R-6	23.2	3.54	10,530
R-7	22.7	4.15	9,880
R-8	37.6	0.56	8,540
R-9	25.5	0.56	11,590
G-1	35.1	4.69	8,980
G-2	23.3	6.90	10,150
G-3	24.2	4.61	9,620
G-4	35.6	3.89	8,020
G-5	39.8	2.93	7,580
G-6	24.0	5.57	9,940
S-1	34.4	2.44	9,620

* Dry Basis

TABLE 5. PROPERTIES OF TOTAL PRODUCT FROM AED BENCH-SCALE FINE COAL PROCESSING UNIT

VERSAR SAMPLE DESIGNATION	ASH CONTENT* (wt. %)	SULFUR CONTENT* (wt. %)	HEAT CONTENT* (BTU/lb.)	WEIGHT RECOVERY (%)	TOTAL ENERGY RECOVERY (%)
B-1	10.4	2.73	13,270	86	91
B-2	13.6	2.44	11,310	78	86
B-3 (8/11)	17.0	2.66	11.620	87	92
B-3 (11)	16.4	1.76	11,710	85	90
B-4	26.9	3.22	10,340	63	81
B-5	25.6	1.72	11,130	80	89
B-6 (UF)	19.4	1.15	12,120	77	87
B-6 (LK)	21.6	2.91	12,010	90	93
B-6 (MIX)	-	-	-	-	-
B-7	21.2	1.20	11,790	84	93
B-8 (H)	18.7	2.58	12,470	74	90
B-8 (V)	17.2	1.31	12,320	82	90
B-9	23.3	1.31	11,630	78	87
R-1	23.2	0.81	11,030	70	83
R-2	26.2	0.93	10,900	81	95
R-3	20.9	3.25	11,020	73	91
R-4	10.3	1.45	11,460	83	90
R-5	17.2	0.76	11,470	76	86
R-6	14.1	2.60	11,730	80	89
R-7	14.9	3.39	11,480	75	87
R-8	24.1	0.59	10,480	69	85
R-9	17.8	0.57	12,720	81	89
G-1	24.1	3.72	11,010	71	87
G-2	15.0	3.96	11,530	82	93
G-3	13.2	3.41	11,100	82	95
G-4	25.9	3.05	9,750	76	92
G-5	30.2	2.25	8,810	73	85
G-6	20.2	4.33	10,970	80	89
S-1	24.2	1.53	11,410	72	86

*Dry Basis

TABLE 6. PROPERTIES OF "FINE FRACTION" PRODUCT FROM AED BENCH-SCALE FINE COAL PROCESSING UNIT

VERSAR SAMPLE DESIGNATION	ASH CONTENT* (wt.%)	SULFUR CONTENT* (wt.%)	HEAT CONTENT* (BTU/lb.)	WEIGHT RECOVERY (%)	ENERGY YIELD (%)
B-1	8.2	2.67	13,640	65	70
B-2	10.8	2.17	12,030	57	67
B-3 (8/11)	13.7	2.50	12,200	63	70
B-3 (11)	13.3	1.61	12,130	62	67
B-4	9.9	3.42	13,140	33	54
B-5	19.6	1.69	12,350	44	54
B-6 (UF)	17.6	1.00	12,550	54	63
B-6 (LK)	21.2	2.29	12,470	53	57
B-6 (MIX)	-	-	-	-	-
B-7	13.0	1.04	13,050	49	59
B-8 (H)	13.5	2.24	13,480	41	55
B-8 (V)	14.0	1.17	12,720	51	57
B-9	21.6	1.31	11,980	49	57
R-1	10.4	0.78	13,000	42	59
R-2	17.1	0.99	12,180	47	62
R-3	10.2	3.16	12,730	46	66
R-4	7.5	1.41	12,490	53	63
R-5	8.8	0.76	12,610	48	59
R-6	10.1	2.53	12,570	55	66
R-7	9.8	3.17	12,210	56	69
R-8	14.2	0.69	12,950	39	59
R-9	12.1	0.59	13,510	48	56
G-1	11.0	3.20	13,280	41	60
G-2	8.4	3.57	12,510	52	64
G-3	9.6	3.23	12,370	54	70
G-4	13.9	2.91	11,620	46	67
G-5	13.3	2.26	12,000	38	60
G-6	11.2	3.73	12,400	49	61
S-1	15.8	1.14	12,960	44	59

*Dry Basis

TABLE 7. RESULTS OF TESTS TO CHARACTERIZE ROM AND PRODUCT COAL SAMPLES FROM PCC PLANTS

PLANT CODE	ESTIMATED WEIGHT RECOVERY	ASH* (wt.%) ROM COAL	ASH* (wt.%) CLEAN COAL	TOTAL SULFUR*(wt.%) ROM COAL	TOTAL SULFUR*(wt.%) CLEAN COAL	HEAT CONTENT* (BTU/lb) ROM COAL	HEAT CONTENT* (BTU/lb) CLEAN COAL
B-1	80	16.70	8.39	4.03	2.81	12,438	13,833
B-2	80	25.30	12.40	3.61	2.48	10,535	11,927
B-3(8/11)	80	25.20	13.28	3.33	2.61	10,725	12,638
B-3(11)	80	22.18	N.A.	2.29	N.A.	11,282	N.A.
B-4	78	43.92	13.17	3.82	3.55	7,950	12,957
B-5	70	32.04	20.17	2.47	2.22	10,068	12,039
B-6(UF)	-	24.77	N.A.	1.79	N.A.	11,207	N.A.
B-6(LK)	-	21.98	N.A.	3.93	N.A.	11,800	N.A.
B-6(MIX)	50**	24.10	10.10	2.30	1.47	11,349	13,703
B-7	75	27.28	12.04	2.15	1.87	10,879	13,370
B-8(H)	-	25.53	N.A.	3.98	N.A.	11,379	N.A.
B-8(V)	-	18.17	N.A.	1.84	N.A.	12,490	N.A.
B-9	55	25.14	9.80	1.74	1.48	11,475	11,042
R-1	41	30.07	12.04	1.31	0.86	10,272	13,163
R-2	60-70	34.12	10.92	1.37	1.43	9,776	13,609
R-3	60-64	32.40	10.17	3.63	3.43	9,612	13,041
R-4	82	28.98	12.70	3.55	1.60	9,812	12,470
R-5	65	27.09	16.08	.95	.83	10,300	12,024
R-6	75	28.40	12.96	3.54	3.35	10,207	12,773
R-7+	67	24.99	11.33	4.07	3.71	10,557	12,557
R-8	60-70	41.66	7.32	.57	.80	8,439	13,969
R-9	60	22.18	5.87	.49	35	12,047	14,734
G-1	80	40.70	11.90	4.10	3.67	8,588	13,232
G-2	73	24.54	N.A.	6.67	N.A.	10,657	N.A.
G-3	70	31.13	8.10	4.61	3.96	9,124	13,289
G-4	68	39.76	12.11	4.19	3.12	8,301	12,724
G-5	60-70	41.26	14.00	2.82	2.97	8,323	12,401
G-6	54	26.20	14.52	5.74	5.20	10,536	12,345
S-1	61***	30.05	9.16	2.52	1.30	10,472	13,981

* Dry Basis

** In plant B-6, Upper Freeport and Lower Kittanning seam coals are introduced to the process by separate belt conveyors. The plant product consists of a metallurgical-grade clean coal and the middlings. Characteristics of the "combined" plant feed were estimated from respective characteristics and mass flow rates of individual feed streams. Chacteristics of the "overall" plant product were estimated from respective characteristics and mass flow rates of the metallurgical grade product and the middlings.

NA The clean coal samples could not be obtained from the PCC plant

*** Typical value of the weight recovery for Plant S-1 is 74 percent according to the PCC plant operator.

+ Flotation circuit not operational during sampling.

The raw and cleaned coal results shown are generally consistent with other data on the operation of PCC facilities(5). However, ROM and clean coal properties vary significantly over short time periods. Thus, the grab samples taken by Versar may not represent "mean" values for the ROM and product coal. Furthermore, the ROM and product coal samples may not "match" in that each may represent coal from different populations which exhibit dissimilar properties. A typical example of the variability which occurs is shown in Figure 7(6). Note that not only is there a great deal of variability in the feed coal, but results from the cleaned coal show no discernable relation to the feed. Because of this variability, one must use caution in using plant sample data as measures of plant performance. The clean coal properties and percentage changes between the ROM and clean coal properties vary significantly with time, and the use of any two samples to represent plant performance will provide data which is at best a measure of relative plant performance on coal from different seams.

D. COMPARATIVE EVALUATION OF AED BENCH-SCALE TEST DATA WITH PCC PLANT PERFORMANCE DATA

Results

Table 8 presents the results of tests by both Versar and AED on ROM feed coal samples after initial processing by Versar. Data presented are: ash content (wt. %), total sulfur content (wt. %), and heat content (Btu/lb). Values from the two independent sources are presented in adjoining columns, for ease of comparison. As is the case in many interlaboratory studies, the reported values for duplicate samples are not as close as one would desire; however, with a few exceptions (such as the sulfur and ash for sample R-4), the variability seems to be random. Interestingly, the least variability is found in the heat content result, usually a more difficult measurement than ash or sulfur.

Table 9 presents for comparison the results of tests to determine ash content of feed and product coals for both the AED Tech 1 Process (total product and fine component) and the PCC plants tested. Numerical values shown are measured ash content (wt. %). Due to the variability of field samples discussed in Section 5.C., the authors have concluded that the best form of comparison between the AED Tech 1 Process and the corresponding PCC plants is a qualitative test - i.e., is the AED process significantly better or worse than the PCC plant? The results of such a comparison are presented in Table 9 along with the data. Table 10 presents information on sulfur content (wt. %) arrayed in the same format as the ash data and in Table 9.

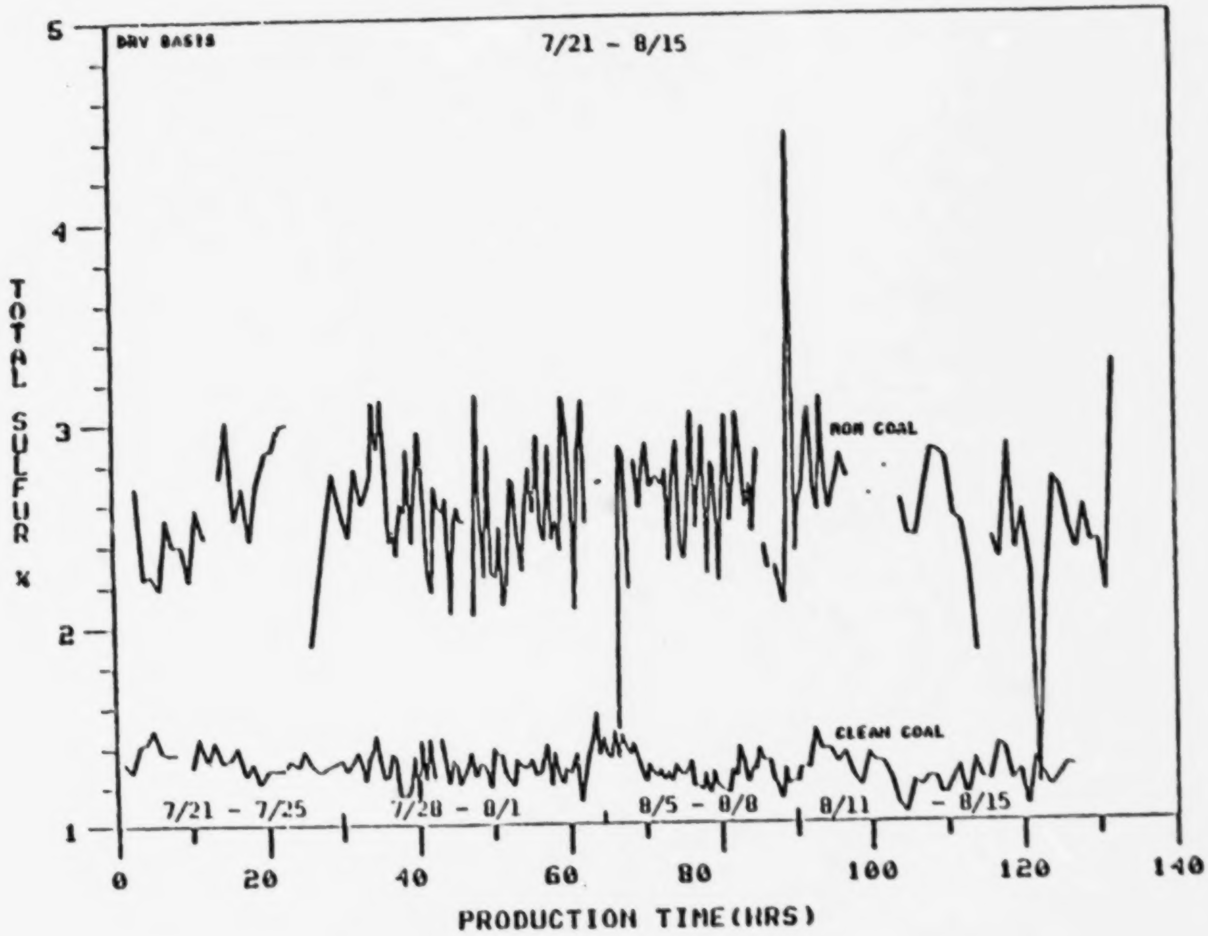


Figure 7. Republic Steel Corporation Hourly Increment Data for Total Sulfur (6)

TABLE 8. COMPARISON OF MEASUREMENTS OF ASH, SULFUR, AND HEAT CONTENT OF ROM COAL SAMPLES BY VERSAR AND AED

SAMPLE NO.	ASH CONTENT (wt.%) VERSAR	ASH CONTENT (wt.%) AED	SULFUR CONTENT (wt.%) VERSAR	SULFUR CONTENT (wt.%) AED	HEAT CONTENT (BTU/LB) VERSAR	HEAT CONTENT (BTU/LB) AED
B-1	16.7	14.4	4.03	3.93	12,440	12,600
B-2	25.3	22.6	3.61	2.70	10,540	10,250
B-3 (8/11)	25.2	19.5	3.33	3.49	10,720	11,080
B-3(11)	22.2	20.0	2.29	2.21	11,280	11,130
B-4	43.9	38.7	3.82	4.02	7,950	8,070
B-5	32.0	32.0	2.47	2.24	10,070	10,010
B-6 (UF)	24.8	26.0	1.79	1.47	11,210	10,830
B-6 (LK)	22.0	23.1	3.93	3.99	11,800	11,540
B-7	27.3	27.8	2.15	1.96	10,880	10,710
B-8 (H)	25.5	31.5	3.98	4.04	11,380	10,170
B-8 (V)	18.2*	24.8*	1.84	1.84	12,490	11,290
B-9	25.1	30.0	1.74	1.79	11,480	10,340
R-1	30.1	34.1	1.31	0.86	10,270	9,210
R-2	34.1	34.4	1.37	0.96	9,780	9,290
R-3	32.4	31.0	3.63	3.74	9,610	8,870
R-4	29.0*	18.9*	3.55*	1.42*	9,810	10,510
R-5	27.1	23.3	0.95	0.83	10,300	10,110
R-6	28.4	23.2	3.54	3.54	10,210	10,530
R-7	25.0	22.7	4.07	4.15	10,560	9,880
R-8	41.7	37.6	0.57	0.56	8,440	8,540
R-9	22.2	25.5	0.49	0.56	12,050	11,590
G-1	40.7	35.1	4.10	4.69	8,590	8,980
G-2	24.5	23.3	6.67	6.90	10,660	10,150
G-3	31.1*	24.2*	4.61	4.61	9,120	9,620
G-4	39.8	35.6	4.19	3.89	8,300	8,020
G-5	41.3	39.8	2.82	2.93	8,320	7,580
G-6	26.2	24.0	5.74	5.57	10,540	9,940
S-1	30.0	34.4	2.52	2.44	10,470	9,620

* Differences which exceed those typical to most of the data.

TABLE 9. COMPARISON OF ASH CONTENT IN PROCESS PRODUCT STREAMS

SAMPLE DESIGNATION	AVERAGE OBSERVED FEED ASH (wt.%)	PCC PROCESS PRODUCT (wt.%)	AED PROCESS TOTAL PRODUCT		AED PROCESS FINE PRODUCT	
			(wt.%)	Comparison	(wt.%)	Comparison
B-1	15.6	8.39	10.4	-	8.2	o
B-2	24.0	12.4	13.6	o	10.8	+
B-3 (8/11)	22.4	13.3	17.0	-	13.7	o
B-3 (11)	21.1	N.A.	16.4	?	13.3	?
B-4	41.3	13.2	26.9	-	9.9	+
B-5	32.0	20.2	25.6	-	19.6	o
B-6 (UF)	25.4	N.A.	19.4	?(-)	17.6	?(-)
B-6 (LK)	22.5	N.A.	21.6	?(-)	21.2	?(-)
B-6 (MIX)	N.A	10.1	N.A.			
B-7	27.5	12.0	21.2	-	13.0	o
B-8 (H)	28.5	N.A.	18.7	?	13.5	?
B-8 (V)	21.5	N.A.	17.2	?	14.0	?
B-9	27.6	9.8	23.3	-	21.6	-
R-1	32.1	12.0	23.2	-	10.4	+
R-2	34.2	10.9	26.2	-	17.1	-
R-3	31.7	10.2	20.9	-	10.2	o
R-4	24.	12.7	10.3	+	7.5	+
R-5	25.2	16.1	17.2	o	8.8	+
R-6	25.8	13.0	14.1	o	10.1	+
R-7	23.8	11.3	14.9	-	9.8	+
R-8	39.6	7.3	24.1	-	14.2	-
R-9	23.8	5.9	17.8	-	12.1	-
G-1	37.9	11.9	24.1	-	11.0	o
G-2	23.9	N.A.	15.0	?	8.4	
G-3	27.6	8.10	13.2	-	9.6	-
G-4	37.7	12.1	25.9	-	13.9	-
G-5	40.6	14.0	30.2	-	13.3	o
G-6	25.1	14.5	20.2	-	11.2	+
S-1	32.2	9.2	24.2	-	15.8	-

Comparison Key:
- AED Process Significantly Worse
o No Significant Difference
+ AED Process Significantly Better

TABLE 10. COMPARISON OF SULFUR CONTENT IN PROCESS PRODUCT STREAMS

			AED PROCESS TOTAL PRODUCT		AED PROCESS FINE PRODUCT	
VERSAR SAMPLE DESIGNATION	AVERAGE OBSERVED FEED S (wt.%)	PCC PROCESS PRODUCT (wt.%)	(wt.%)	Comparison	(wt.%)	Comparison
B-1	3.98	2.81	2.73	o	2.67	+
B-2	3.16	2.48	2.44	o	2.17	+
B-3(8/11)	3.41	2.61	2.66	o	2.50	+
B-3(11)	2.25	N.A.	1.76	?	1.61	?
B-4	3.92	3.55	3.22	+	3.42	o
B-5	2.36	2.22	1.72	+	1.69	+
B-6(UF)	1.63	N.A.	1.15	?	1.00	?
B-6(LK)	3.96	N.A.	2.91	?	2.29	?
B-6(MIX)	-	1.47				
B-7	2.06	1.87	1.20	+	1.04	+
B-8(H)	4.01	N.A.	2.58	?	2.24	?
B-8(V)	1.84	N.A.	1.31	?	1.17	?
B-9	1.76	1.48	1.31	+	1.31	+
R-1	1.08	0.86	0.81	o	0.78	+
R-2	1.16	1.43	0.93	+	.99	+
R-3	3.68	3.43	3.25	+	3.16	+
R-4	2.48	1.60	1.45	+	1.41	+
R-5	0.89	0.83	.76	o	0.76	o
R-6	3.54	3.35	2.60	+	2.53	+
R-7	4.11	3.71	3.39	+	3.17	+
R-8	0.56	0.80	0.59	+	0.69	o
R-9	0.52	0.35	0.57	-	0.59	-
G-1	4.40	3.67	3.72	o	3.20	+
G-2	6.78	N.A.	3.96	?	3.57	?
G-3	4.61	3.96	3.41	+	3.23	+
G-4	4.04	3.12	3.05	o	2.91	+
G-5	2.87	2.97	2.25	+	2.26	+
G-6	5.66	5.20	4.33	+	3.73	+
S-1	2.48	1.30	1.53	-	1.14	+

Comparison Key:
- AED Process Significantly Worse
o No Significant Difference
+ AED Process Significantly Better

Comparative Analysis

Ash Removal--

The AED Tech 1 Process seems to perform worse on ash removal than the PCC plants sampled. Reference to Table 9 indicates that the Tech 1 Process gave worse results in all but four cases when the total product is considered. If only the fine fraction product is examined, the Tech 1 Process was better on eight, worse on seven and the same on seven samples. The relatively lower comparative results on total ash removal may be attributed to the high inorganic loading of the ROM samples or to the relative inefficiency of the Tech 1 Process tested in removing ash in the very fine and ultrafine particle size ranges. The relatively superior performance on the fine particle size fraction is an indication of the inherent strength of the process concept. There also may be an economic advantage associated with good ash removal in this size range, since these ash particles are thought to be largely responsible for the formation of slag on boiler tubes(7,8).

Sulfur Removal--

The data show that the AED Tech 1 Process generally outperforms the PCC plants tested (see Table 10). The total product is better than the PCC samples in thirteen cases, equivalent in seven and worse in two. The fine fraction results show improvement in eighteen cases, no difference in three, and a worsening in a single case. These improved comparisons (for sulfur vs ash) are likely the result of differences in the performance of the PCC processes. The ash removal results for PCC plants probably reflect the presence of easily removed, mined rock in the ROM coal, which when removed appears to enhance ash removal results. The sulfur is thought to be incorporated into the coal matrix in relatively smaller inclusions (which tend to be harder to remove for most PCC processes).

Energy Recovery--

The recovery of energy values from the ROM coal is a key factor in the economics of any coal cleaning process. In this study, data have been developed which provide a very crude basis for comparison of computed energy recovery by the AED Tech 1 Process with that estimated for the PCC plants sampled. These values are presented in Table 11. Energy recovery values for the PCC plants were calculated from the measured heat content of the PCC product sample and the estimated weight recovery of the plant as provided by the operator. The sample variability (discussed above) for the PCC plants resulted in energy recoveries ranging from 52 to 127 percent (which is impossible). Obviously, it is not possible to make meaningful comparisons from the existing data. However, the energy recovery data for the AED process appear to be within the competitive range: viz. 85 to 95 percent, averaging 89 percent. Comparison shows the AED Tech 1 Process to be significantly better in nine cases, significantly worse in seven cases, and not significantly different in five cases. The best conclusion seems to be that the AED Tech 1 Process is within the competitive range regarding energy recovery.

TABLE 11. COMPARISON OF TOTAL ENERGY RECOVERY ESTIMATES FOR SELECTED TESTS

VERSAR SAMPLE DESIGNATION	AED PROCESS TOTAL ENERGY RECOVERY %	PCC PLANT ESTIMATED ENERGY RECOVERY %	COMPARISON
B-1	91	89	o
B-2	86	N.A.	?
B-3(8/11)	92	94	o
B-3(11)	90	N.A.	?
B-4	81	127	-
B-5	89	84	+
B-6(UF)	87	N.A.	?(+)
B-6(LK)	93	N.A.	?(+)
B-6(MIX)		60	
B-7	93	92	o
B-8(H)	90	N.A.	?
B-8(V)	90	N.A.	?
B-9	87	67	+
R-1	83	53	+
R-2	95	84-97	o
R-3	91	81-87	+
R-4	90	103	-
R-5	86	76	+
R-6	89	94	o
R-7	87	80	+
R-8	85	100-115	-
R-9	89	73	+
G-1	87	123	-
G-2	93	N.A.	?
G-3	95	102	-
G-4	92	104	-
G-5	85	90-104	-
G-6	89	63	+
S-1	86	76	+

Comparison Key:
- AED Process Significantly Worse
o No Significant Difference
+ AED Process Significantly Better

E. ADDITIONAL INFORMATION

Since the completion (in 1981) of the coal processing tests which are the subject of this report, significant additional information has been generated relevant to the AED coal cleaning technology:

- The optimization of system operating variables has been explored for a single coal, resulting in improved ash and sulfur removal.
- Pre-cleaning of ROM coal has been found to improve overall ash removal by the AED Tech 1 Process.
- An extension of the AED electrostatic roll separator concept has augmented the capability of the system to allow it to process particles as small as 1 micron (Ultrafine Coal Cleaning Process).

These three items bear both on the overall evaluation of the electrostatic separation approach and on the interpretation of the data generated in this study. Hence, a brief discussion of each of these items is presented here.

Optimization of Operating Variables

In all of the AED Tech 1 Process tests presented here, the run parameters of the Tech 1 unit (voltage levels, drum rotation speed, flow sheet design, moisture levels, etc.) were set at constant values. Since a facility operating at full scale would certainly explore the optimization of these parameters, a preliminary study of this has been made by AED. After the completion of the protocol tests, one coal sample (Sample B-9) was rerun several times, with the objective of optimizing the system's performance on that coal, the Lower Kittanning seam from Somerset County, PA. In the optimizing runs the voltage was decreased and the roll velocity increased.

These preliminary runs yielded the results summarized below. Note that both sulfur and ash reduction improved, while Btu recovery remained constant.

	Original Run	Optimized Run
Sulfur (wt. %)	1.31	1.15
Ash (wt. %)	23.3	22.4
Yield by weight (%)	78	74
Btu yield	87	87

It should be noted that these results are only partially optimized. Although several runs were made before the remaining coal sample was exhausted, it is not clear that this represents all of the improvement possible.

The Impact of Precleaning on Process Performance

As discussed in Section 5.B, much of the inorganic material in the ROM coal samples processed by AED found its way into the ultrafine size fraction during the pulverization, prior to processing in the Tech 1 unit. If this is the result of a preferential size reduction of the ash-forming components in the coal, as is suspected, then the data show that by pulverizing the sample one is converting some coarse (and hence relatively easily removed) inorganic matter into very small particles before attempting its removal. Since most PCC plants include an inexpensive, coarse separation step before processing a more finely ground material(5), and since several such steps are dry processes compatible with the AED concept, it seemed logical to explore such an option here. The results of two tests runs on the AED Tech 1 Process are presented in Figures 8 and 9. In these tests, Pittsburgh #8 coal produced at the #4 Powhatan mine (Belmont County, Ohio) was provided to AED in a ROM condition and a washed condition. Details of the PCC process used are not available; however, it reduced coal sulfur from 4.66 wt. % to 3.85 wt. % and ash from 32 wt. % to 15.6 wt. %. It is significant to note that in cleaning the unwashed coal, the AED Tech 1 Process outperformed the PCC plant in sulfur removal (just as in the tests reported above), but performed significantly worse in total ash reduction. The observed values are tabulated below:

	wt.% S	wt.% Ash
ROM Coal	4.66	32.0
PCC Plant Product	3.85	15.6
AED Process Product	2.75	19.0

Even more significant are the results of cleaning the PCC Plant product in the AED Tech 1 system. Both sulfur and ash levels are substantially improved:

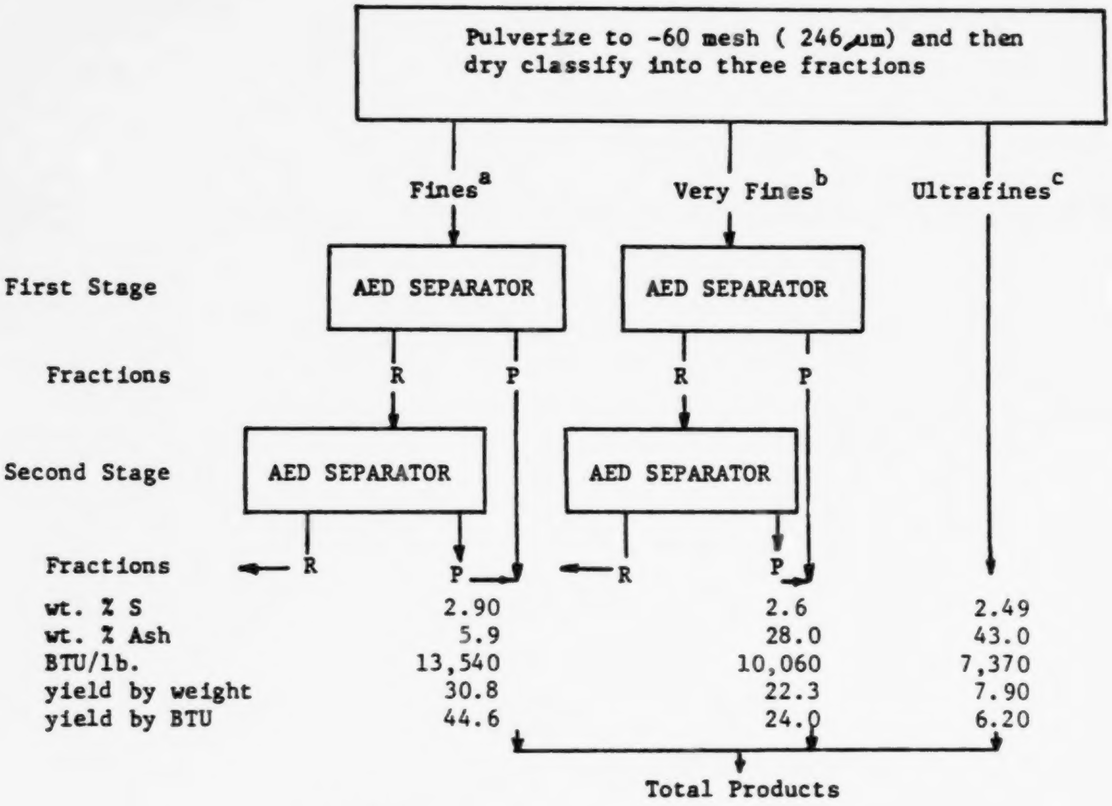
	wt.% S	Wt.% Ash
PCC Plant Product	3.85	15.6
AED Tech 1 Process Results on PCC Plant Product	2.66	13.0

Although a single data set such as this does not prove the hypothesis (due to the oft-mentioned variation in properties of coal seams), it does support it.

Capability to Process Very Fine/Ultrafine Material

Aware of the inadequacy of the AED Tech 1 Process in the small particle regime, AED has engaged in development of a compatible dry electrostatic process capable of operating in this smaller size range. Although the nature of the process is still proprietary, pending suitable protection of intellectual rights, some preliminary results are presented here to demonstrate its potential. Figures 10 and 11 summarize the results of two tests run with this improved system on a second sample of coal B-3 provided by Versar. The difference between the tests is due to intentional variation of the process controls of the improved system in order to present a range of results. Note that in both cases the minus 53 microns (very fine and ultrafine) material is beneficiated substantially by the improved system both with regard to ash and sulfur content.

wt. % S	4.66
wt. % Ash	32.0
BTU/lb	9,354


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Total Products

	Fines	Very Fines	Ultrafines
wt. % S	2.90	2.6	2.49
wt. % Ash	5.9	28.0	43.0
BTU/lb.	13,540	10,060	7,370
yield by weight	30.8	22.3	7.90
yield by BTU	44.6	24.0	6.20

Total Products

wt. % S	2.75
wt. % Ash	19.0
BTU/lb.	11,467
yield by weight	61
yield by BTU	75

a - Fines are 60 x 270 mesh (246 x 53 µm)

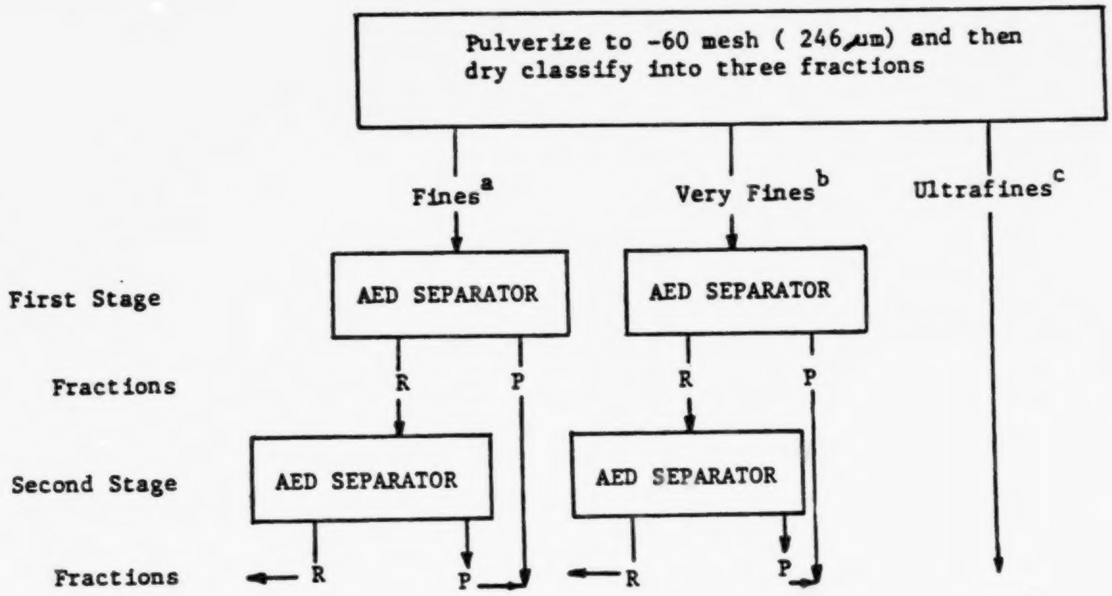
b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

NOTE: R = Rejects
P = Products

Figure 8. AED System Results - Two Stages
Coal: Pittsburgh No. 8 - Unwashed

wt. % S	3.85
wt. % Ash	15.6
BTU/lb	11,980


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines P	Very Fines P	Ultrafines
wt. % S	2.49	2.89	2.77
wt. % Ash	9.0	14.0	26.1
BTU/lb.	13,230	12,190	10,060
yield by weight	49	32	13
yield by BTU	54	33	11

Total Products

wt. % S	2.66
wt. % Ash	13.0
BTU/lb.	12,450
yield by weight	93
yield by BTU	97

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

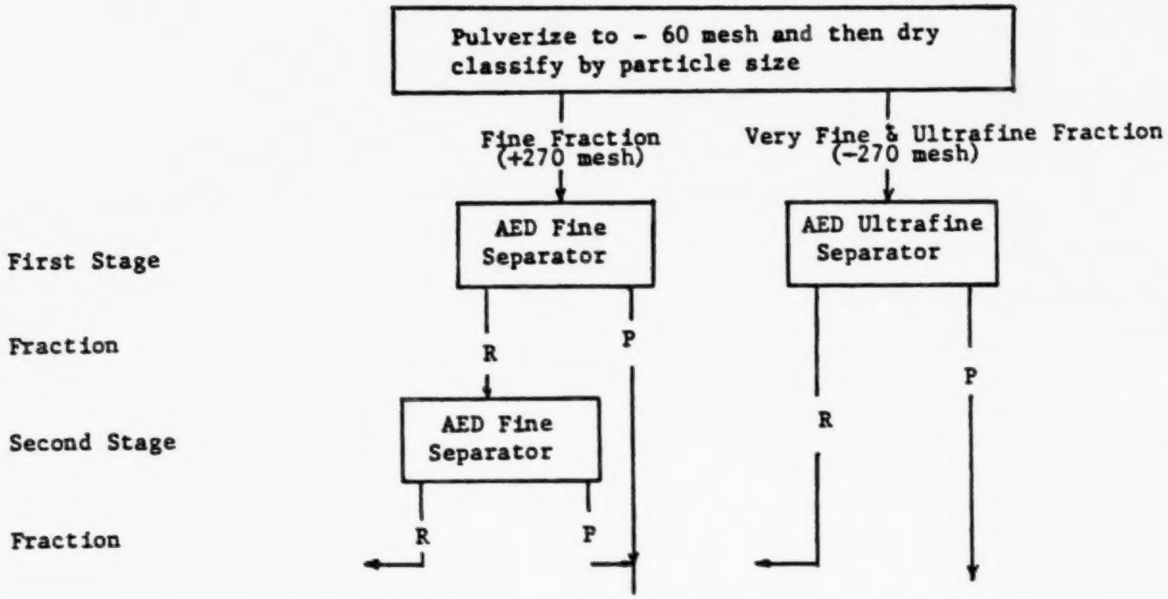
c - Ultrafines are - 20 µm

NOTE: R = Rejects
P = Products

Figure 9. AED System Results - Two Stages
Coal: Pittsburgh No. 8 - Washed

Total Feed Properties

wt. % S	3.13
wt. % Ash	19.6
BTU/lb.	11,008


Pulverize to - 60 mesh and then dry classify by particle size
Fine Fraction (+270 mesh)
Very Fine & Ultrafine Fraction (-270 mesh)
First Stage
AED Fine Separator
AED Ultrafine Separator
Fraction
R
P
R
P
Second Stage
AED Fine Separator
R
Fraction
R
P

Properties		
wt. % S	2.34	2.42
wt. % Ash	14.5	8.9
BTU/lb.	11,884	12,871
yield (by weight)	30.70	48.70
yield (by BTU)	33.20	57.00

Total Product

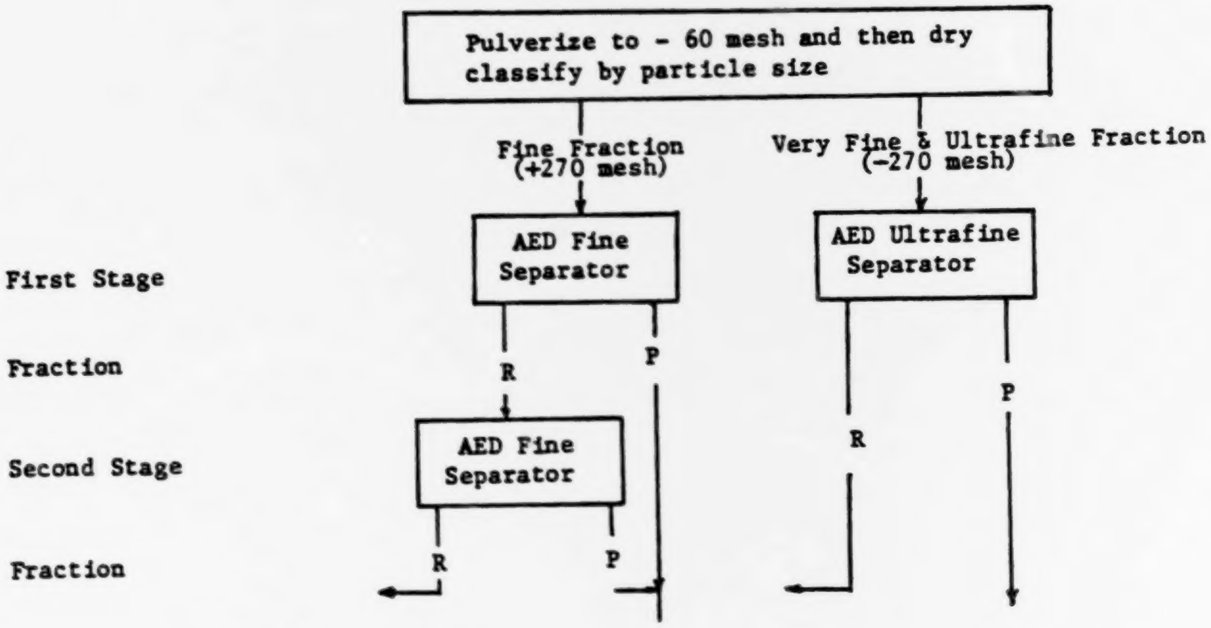
wt. % S	2.39
wt. % Ash	11.0
BTU/lb.	12,489
yield (by weight)	79.4
yield (by BTU)	90.1

Note: R = Rejects
P = Products

Figure 10. AED System Results - Two Stages
Coal: B-3 Option No. 1

Total Feed Properties

wt. % S	3.13
wt. % Ash	19.6
BTU/lb.	11,008


Pulverize to - 60 mesh and then dry classify by particle size
Fine Fraction (+270 mesh)
Very Fine & Ultrafine Fraction (-270 mesh)
AED Fine Separator
AED Ultrafine Separator
First Stage
Fraction
R
P
R
P
AED Fine Separator
Second Stage
Fraction
R
P

Properties

wt. % S	2.13	1.87
wt. % Ash	12.6	3.9
BTU/lb.	12,162	13,774
yield (by weight)	25.0	36.1
yield (by BTU)	27.7	45.1

Total Product

wt. % S	1.98
wt. % Ash	7.3
BTU/lb.	13,113
yield (by weight)	61.1
yield (by BTU)	72.8

Note: R = Rejects
P = Products

Figure 11. AED System Results - Two Stages
Coal: B-3 Option No. 2

SECTION 6

RESULTS OF PRELIMINARY ECONOMIC ANALYSES

A. OVERVIEW

One of the overall objectives of this project was to attempt to perform a cost comparison of conventional PCC technology with the AED Tech 1 Process. Conceptual designs and preliminary economic analyses were developed for six of the PCC plants sampled under this program. This work was conducted by Versar, Inc. In addition, AED, Inc., in collaboration with Stone & Webster Engineering Corporation, developed two conceptual designs for the AED Tech 1 Process and carried out economic analyses for these designs. Both economic studies were conducted in accordance with EPA guidelines for the economic analysis of process industries. This section of the report describes the efforts made to develop this information and discusses the results.

B. PCC PLANTS

The six PCC designs used in this study were based on the designs of actual PCC plants visited during the sampling program. However, these designs were slightly modified whenever necessary. The PCC processes selected are coded B-1, B-3, R-3, R-6, R-8, and S-1.

Each plant was sized to a feed coal flow rate of 544 metric tons per hour (600 tons per hour) on a surface moisture-free basis. The annual capacity throughput was taken to be 1.81 million metric tons (2.0 million tons), based on a 13.3-hour operating day and 250 days per year. The cost analysis prepared for each design, based on mid-1978 dollars, is presented in detail in Appendix C. It includes process flow diagrams, a breakdown of capital costs, and a detailed analysis of the basis for annualized costs, including waste disposal costs. Unit costs for product coals are estimated from the total annualized costs, the feed rate basis and operator estimates of material and energy recovery factors for the plant.

The results of cost analyses of the six PCC plants described in this section are summarized in Table 12. It should be kept in mind that the information provided here is based on a conceptual plant size (544 mtph feed flowrate), using the design and cost assumptions documented in Appendix C. It should also be remembered that the feed and clean coal characteristics were obtained from analysis of grab samples which may not be representative of the plant feed and product streams.

The turnkey costs for the six PCC plants varied from 8.3 to 12.1 million (mid-1978) dollars, and the annualized costs (excluding the cost of coal) were between 4.6 and 5.3 million dollars. The cleaning cost per ton of clean coal was estimated to be the lowest for plant R-6. However, plant B-1 was found to have the lowest cleaning costs when these costs are expressed per unit of energy in the clean coal.

TABLE 12. COST ESTIMATE FOR CLEANING COAL AT SIX PCC PLANTS

	PLANTS					
	B-1	B-3	R-3	R-6	R-8	S-1
Total Turnkey Cost* ($1000)	9,885	12,135	8,364	8,689	11,600	11,313
Total Annualized Costs* ($1000)	4,631	5,304	4,389	4,305	5,207	5,113
Weight Recovery** (%)	80	80	64	75	60	61
Cleaning Costs*						
$/ton clean coal***	3.03	3.47	3.58	3.00	4.61	4.28
¢/10^6 Btu clean coal	11.0	13.7	13.7	11.7	16.5	15.3

* Mid-1978 dollars. Does not include the cost of coal and the profit.
** As received basis, estimated by plant operator.
*** Moisture free basis.

C. APPLICATION OF THE AED PROCESS

For the purposes of economic comparison, two design concepts were formulated using the AED Process: one in which the process cleans coal at an electric utility and a second where the process operates at the minemouth. At the utility, the AED Process accepts pulverized coal from the coal pulverizer, cleans it and sends it to the boiler. Additional costs are included in the design to cover the expense of maintaining an inert atmosphere (flue gas) around the pulverized coal during processing. For the design at the coal mine, costs are included for briquetting the cleaned coal after treatment so that it can be shipped safely.

Both design concepts were sized to a clean coal production rate of 113.4 metric tons per hour (125 tons per hour). Annual capacity is based on 6,000 hours per year at a coal mine. The annualized costs developed include the cost of additional coal feed in the power plant case. Costs for waste disposal were not included in the analyses.

The detailed cost analysis cases are presented in Appendix D. These costs are calculated in mid-1980 dollars. These costs can be converted to a mid-1978 basis by dividing by 1.147. The material presented in Appendix D includes a detailed process material flow sheet, a breakdown of capital costs and a detailed analysis of the basis for developing annualized costs.

Note that the AED Process cost estimates do not include the costs of waste disposal. These and other adjustments must be made to provide estimates which are strictly comparable to the Versar estimates for PCC plants.

The results of these analyses are presented in Table 13.

TABLE 13. COST ESTIMATE FOR CLEANING COAL USING AED PROCESS

	Power Plant	Mine Mouth
Total Turnkey Cost* ($1000)	10,080	15,310
Total Annualized Costs* (1000)	2,660	2,758
Cleaning Costs		
$/ton product coal	2.41	3.21
¢/10^6 Btu product coal	9.6	13.6

* Mid 1978-dollars

D. COMPARISON/DISCUSSION

Substantial differences in the design basis for the studies by AED/Stone and Webster and those by Versar cloud any attempts at comparison. The reader is referred to Appendices C and D for these differences. Clearly the unit costs are in the same ballpark for both the AED Process and the PCC plants, but substantial refinement is needed before meaningful comparisons can be made. Issues of reliability, lifetime, maintenance, waste disposal, and interfacing need closer examination.

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8. "Ash Deposition Research on Canadian Lignites," by A.D. Winship and F. Bender. Proceedings: U.S. Bureau of Mines - Univ. of North Dakota Symposium, May 1969, Info. Circular 8471.

APPENDIX A

VERSAR, INC.

COAL TEST RESULTS AND PROCEDURES

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A.1 ANALYSIS OF SAMPLES AND LABORATORY RESULTS

All the feed and clean coal samples were analyzed for moisture, ash, heat content, pyritic sulfur, and total sulfur. The analytical methods used are listed in Table 3, of the main report and the detailed procedures are presented in Section A.2 of this Appendix.

To ensure that the coal analyses data were precise and accurate, a quality control program was followed. All the samples were analyzed in duplicate and the data were recorded on a master form. The data were then entered into a programmable calculator which then calculated the results on an as-determined basis, as-received basis, dry weight basis, and dry-ash free basis. The acceptability of duplicate analyses were based upon precision criteria for repeatability established by the individual test methods. Comparisons of duplicates were made using this criteria and samples were re-analyzed as necessary.

The analytical results of the raw and clean coal samples form PCC plants are presented in Table A-1. These results may be quite different from the coal characteristics representative of the plant feed and product streams, since the samples we collected instantaneously by grab sampling methods. The ROM and clean coal characteristics provided by the PCC plant operators are given in Table A-2 for comparison purposes.

TABLE A-1. ANALYTICAL RESULTS OF ROM AND CLEAN COAL FROM PCC PLANTS

Plant Code	Estimated Weight Recovery (%)	Coal Seam	State	County	Total Moisture (%)		Ash* (%)			Total Sulfur* (%)			Pyritic Sulfur (%)			Heat Content* (Btu/lb)			SO_2 Emission Parameter (lb $SO_2/10^6$ Btu)		
					ROM Coal	Clean Coal	ROM Coal	Clean Coal	Reduction	ROM Coal	Clean Coal	Reduction	ROM Coal	Clean Coal	Reduction	ROM Coal	Clean Coal	Enhancement (%)	ROM Coal	Clean Coal	Reduction (%)
B-1	80	Pittsburgh No. 8	WV	Harrison	3.70	ND	16.70	8.39	49.8	4.03	2.01	30.3	2.29	1.28	44.1	12,438	13,833	11.22	6.48	5.26	30.3
B-2	80	Ohio No. 6	OH	Perry	8.98	11.10	25.30	12.40	51.0	3.61	2.48	31.8	2.34	1.24	47.0	10,535	11,927	13.21	6.15	4.16	32.4
B-3	80	No. 8-11	OH	Belmont	5.67	7.73	25.20	13.28	47.3	3.33	2.61	21.6	2.19	1.43	31.7	10,725	12,638	17.84	6.20	4.13	33.4
B-3	80	No. 11	OH	Belmont	4.52	NA	22.18	NA	NA	2.29	NA	NA	1.59	NA	NA	11,282	NA	NA	4.05	NA	NA
B-4	78	Pittsburgh No. 8	WV	Marshall	9.06	5.77	43.92	13.17	70.0	3.82	3.55	7.1	2.41	1.72	28.6	7,950	12,957	62.98	9.60	5.48	42.9
B-5	70	Undisclosed	PA	Green	3.35	8.80	32.04	20.17	37.0	2.47	2.22	10.1	1.91	1.21	36.6	10,068	12,039	19,58	4.91	3.68	25.1
B-6	--	Upper Freeport	PA	Armstrong	2.16	NA	24.77	NA	NA	1.79	NA	NA	1.13	NA	NA	11,207	NA	NA	3.18	NA	NA
B-6	--	Lower Kittanning	PA	Armstrong	2.53	NA	21.98	NA	NA	3.93	NA	NA	2.73	NA	NA	11,800	NA	NA	6.64	NA	NA
B-6	50	U. Freeport, L. Kittanning**	PA	Armstrong	2.25	6.24	24.10	10.10	58.1	2.30	1.47	36.1	1.51	0.82	45.7	11,349	13,703	20.7	4.05	2.15	46.9
B-7	75	Pittsburgh No. 8	PA	Allegheny	4.55	5.88	27.28	12.04	55.9	2.15	1.87	13.0	1.23	1.08	12.2	10,879	13,370	22.90	3.94	2.79	29.2
B-8	--	Upper Freeport, East	PA	Indiana	3.02	NA	25.53	NA	NA	3.98	NA	NA	2.82	NA	NA	11,379	NA	NA	6.98	NA	NA
B-8	--	Upper Freeport, East	PA	Indiana	4.47	NA	18.17	NA	NA	1.84	NA	NA	1.16	NA	NA	12,490	NA	NA	2.96	NA	NA
B-9	55	Lower Kittanning, B	PA	Somerset	6.80	9.70	25.14	9.80	61.0	1.74	1.48	14.9	1.11	0.74	33.3	11,475	11,042	22.37	3.04	2.10	30.9
R-1	41	Jellico	TN	Clairborne	2.39	3.20	30.07	12.04	60.0	1.31	0.86	34.4	0.91	0.47	48.4	10,272	13,163	28.14	2.54	1.29	49.2
R-2	60-70	Mary Lee	AL	Jefferson	6.40	7.64	34.12	10.92	68.0	1.37	1.41	(0.04)	0.94	0.58	38.3	9,776	13,609	39.21	2.80	2.10	25.0
R-3	60-64	KY No. 11	KY	Union	7.34	8.12	32.40	10.17	68.6	3.63	3.43	5.5	2.14	1.32	38.3	9,612	13,041	35.67	7.55	5.26	30.3
R-4	82	KY No. 13	KY	Ohio	13.02	12.51	28.98	12.70	56.2	3.55	1.60	54.9	0.94	0.63	33.0	9,812	12,470	27.09	7.28	2.56	61.6
R-5	65	IL No. 6	IL	Franklin	9.74	10.97	27.09	16.08	40.6	0.95	0.83	12.6	0.47	0.25	46.8	10,300	12,024	16.74	1.84	1.38	25.0
R-6	75	IL No. 6	IL	Williamson	5.96	7.36	28.40	12.96	54.4	3.54	3.35	5.4	2.18	1.39	36.2	10,207	12,773	25.14	6.93	5.24	24.4
R-7··	67	No. 6	IN	Warrick	7.92	9.28	24.99	11.33	54.7	4.07	3.71	8.8	2.56	1.73	32.4	10,557	12,557	18.94	7.71	5.84	24.2
R-8	60-70	L. Elkhorn - Elkhorn No. 3	KY	Pike	3.75	8.26	41.66	7.32	82.4	0.57	0.80	(28.8)	0.30	0.24	20.0	8,439	13,969	65.33	1.36	1.14	16.2
G-9	60	Pocahontas No. 4	WV	Mercer	11.60	2.90	22.18	5.87	73.5	0.49	0.35	28.6	0.13	0.17	(23.5)	12,047	14,734	22.30	0.81	0.47	42.0
G-1	80	Fleming	KS	Bourbon	4.46	3.67	40.70	11.90	70.8	4.10	3.67	10.5	3.12	1.90	39.1	8,588	13,232	54.08	9.52	5.53	41.9
G-2	73	Bee Veer	MO	Randolph	10.82	NA	24.54	NA	NA	6.67	NA	NA	4.37	NA	NA	10,657	NA	NA	12.51	NA	NA
G-3	70	IL No. 2	IL	Fulton	13.85	17.50	31.13	8.10	74.0	4.61	3.96	14.1	3.26	2.19	32.8	9,124	13,289	45.65	10.10	5.88	41.8
G-4	68	IL No. 6	IL	Peoria	10.78	13.20	39.76	12.11	67.5	4.19	3.12	25.5	2.86	1.15	59.8	8,301	12,724	53.28	10.00	4.90	51.4
G-5	60-70	IL No. 5	IL	Knox	10.84	13.70	41.26	14.00	66.1	2.82	2.97	(5.3)	1.55	1.03	33.5	8,323	12,401	49.00	6.77	4.78	29.4
G-6	54	No. 3	IN	Clay	9.06	8.61	26.20	14.52	44.6	5.74	5.20	9.4	3.21	2.14	33.3	10,536	12,345	17.17	10.88	8.42	22.6
S-1	61**	Lower Kittanning	WV	Barbour	4.69	5.39	30.05	9.16	69.5	2.52	1.30	48.4	1.80	0.54	70.0	10,472	13,981	25.10	4.91	1.86	61.3

* Dry Basis.

( ) Increase.

+ In Plant B.G., Upper Freeport and Lower Kittanning seam coals are introduced to the process by separate belt conveyors. The plant product consists of the metallurgical-grade clean coal and the middlings

** Characteristics of the "combined" plant feed were estimated from respective characteristics and mass flow rates of individual feed streams. Characteristics of the "overall" plant product were estimated from respective characteristics and mass flow rates of the metallurgical grade product and the middlings.

NA The clean coal samples could not be obtained from the PCC plant.

ND Not analyzed.

·· Flotation circuit not operational during sampling.

· These values were either calculated from measured product and feed flow rates during sampling, or given as typical by the PCC operator.

a Typical value of the weight recovery for Plant S-1 is 74 percent according to the PCC plant operator.

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TABLE A-2. ROM AND CLEAN COAL CHARACTERISTICS PROVIDED BY THE OPERATORS OF THE PCC PLANTS SAMPLED*

Plant Code	Total Moisture %		Ash %		Total Sulfur %		Pyritic Sulfur %		Heat Content (Btu/lb)		Time Basis for Coal Data
	ROM Coal	Clean Coal	ROM Coal	Clean Coal	ROM Coal	Clean Coal	ROM Coal	Clean Coal	ROM Coal	Clean Coal	
B-1		9.0		7.5		3.0				12,655	December 1980
B-2	9.0	11.1	20.1	9.9	3.2	2.2			10,000	11,321	December 1980
B-3	7.0	9.0	16.0		3.5				11,650		December 1980
B-4		8.9		10.5		4.1				13,297	December 1980
B-5	4.0	7.3	32.0	16.3	2.3	2.0			11,000	11,421	Feed data: 1967 Product data: Sept 1980
B-6**			28.4		2.5				10,800		November 1980
B-7		5.8	22.5	8.0	1.4	1.3			11,676	13,210	December 1980
B-8											
B-9		9.1	32.0	8.9	1.97	1.10					December 1980
R-1											
R-2											
R-3		12.5	37.5	10.5	3.8	3.4			8,729	12,760	December 1980
R-4	11.7	14.6	14.8	8.8	1.5	1.6			10,394	10,985	November 1980
R-5											
R-6			11.0		2.5				11,800		December 1980
R-7											
R-8											
R-9		5.5		6.3		0.9					December 1980
G-1											
G-2	13.9		20.7		5.2				9,147		December 1980
G-3	20.0	18.0	14.0	6.5	5.5	3.3				11,235	December 1980
G-4			14.0	7.0	3.3				10,750	11,750	December 1980
G-5		17.5		10.5	3.5	2.4				10,550	December 1980
G-6		10.0	22.5	13.8	4.9	4.0			10,500	10,902	December 1980
S-1	4.5	7.4	32.9	9.2	2.6	1.3	1.6	0.5	9,944	13,959	April 1980

* Blank areas on table indicate data which were not provided by PCC plant operators.

** Combined feed coal characteristics were obtained from the weighted average of the two individual feed coal characteristics to Plant B-6.

A.2 DETAILS OF COAL ANALYSIS METHODS

1. DETERMINATION OF TOTAL SULFUR IN COAL
(High Frequency Combustion Titration Procedure)

Summary of Method

Total sulfur is determined by combusting a weighed sample of coal at a high temperature in a stream of oxygen. The sulfur oxides formed pass into a titration vessel containing a dilute acid solution, potassium iodate, potassium iodide, and starch indicator. The sulfur dioxide reacts with the blue starch iodine complex and bleaches it to form sulfuric acid and hydrogen iodide (HI). Potassium iodate titrant is added automatically until all the sulfur dioxide has been titrated. The amount of standard iodate consumed during the combustion is a direct measure of the sulfur content of the sample.

National Bureau of Standards reference samples for sulfur in coal and other commercially available certified standards are used to calibrate the system on a daily basis.

Apparatus

- Leco high frequency induction furnace
- Automatic sulfur titrator
- Oxygen purifying train
- Analytical balance, sensitive to 0.1 mg

Reagents and Materials

- Hydrochloric acid (15 + 985)
- Potassium iodate (0.444 g/1)
- Arrowroot starch solution (29/200 ml)
  + 6 g potassium iodide
- Deionized water, reagent grade
- Iron powder accelerator
- Vanadium Pentoxide accelerator
- Oxygen
- Coal standards - National Bureau of Standards
  1.62% (±.03) % sulfur
- Combustion crucibles + porous covers

Procedure

- Weigh 0.1 g of analysis sample into a preweighed combustion crucible containing one large scoop (LECO) of vanadium pentoxide. Cover the sample with two small scoops of iron powder followed by another large scoop of vanadium pentoxide. Place a porous ceramic cover on the crucible.

- Fill the buret with potassium iodate solution. Add dilute hydrochloric acid to the titration vessel and 5 ml of starch solution. Adjust the endpoint control to give a medium blue color.

- Preheat the combustion furnace for 5 minutes. Set the igniter timer for 6 minutes and adjust the oxygen flow rate at 1.0l/min. Place the crucible containing the sample, accelerator, and cover on the pedestal. Set the automatic titrator switch to titrate and start the igniter timer. After 1 minute, the igniter will glow red and raise the pedestal and crucible into the induction tube. Combust the sample for 5 minutes. The sulfur dioxide produced is automatically titrated to the preset endpoint. The iodate consumed is directly proportional to the sulfur content.

- Prepare reagent blanks using the same procedure but without a sample.

- Prepare and run ten replicates of a standard coal sample using the above procedure. Average the final buret readings to use in the "F" factor calculation.

Calculations

- % Total Sulfur = A x B x F
  - A = KIO_3 titrant consumed
  - B = Correction factor for KIO_3 solution
  - F = Calculated from standard coal samples

- $F = \frac{C \times D}{A \times B}$
  - C = % sulfur of standard
  - D = Sample weight (g)
  - A = Average KIO_3 used for the ten standard replicates
  - B = KIO_3 correction factor

2. STANDARD TEST METHOD FOR PYRITIC SULFUR IN COAL (ASTMD - 2492)

Summary of Method

Pyritic sulfur is determined by extracting a weighed sample of coal with dilute nitric acid followed by atomic absorption determination of iron in the extract as a measure of pyritic sulfur. Extraction of pyritic sulfur from coal with dilute nitric acid involves oxidation of ferrous iron to ferric and sulfide sulfur to sulfate, both of which are soluble in nitric acid. Because the extraction dissolves sulfate and pyritic sulfur plus a small amount of organic sulfur, the dissolved sulfur is not a reliable measure of pyritic sulfur. Consequently, sulfate sulfur must be removed first, through a hydrochloric acid digestion, before the sample can be digested with nitric acid for pyritic sulfur.

Apparatus

- Balance, sensitive to 1 mg
- Hot plate
- Atomic Absorption Spectrophotometer

Reagents and Materials

- Hydrochloric Acid (2 + 3), ACS grade
- Nitric Acid (1 + 7), ACS grade
- Deionized Water, reagent grade
- Filters, glass fiber with suitable holder
- Flasks, 250 ml Erlenmeyer

Procedure

- Extraction of Pyritic Sulfur - Weigh to the nearest 0.1 mg about 5 grams of seived sample (60 mesh) and transfer to a 250 ml flask. Add 50 ml of dilute HCl and boil for 30 minutes. Filter the residue through a glass fiber filter and discard the filtrate containing the soluble sulfates. Transfer the residue and filter to the 250 ml flask, add 50 ml HNO_3 and either boil for 30 minutes or let stand overnight at room temperature. Cool the mixture, filter and volumetrically dilute to 250 ml. Prepare reagent blanks using the same procedure but without a sample.

- Determination of Iron by Atomic Absorption - Using a certified stock solution, iron standards are prepared to cover the expected range of iron concentrations (0-400 mg/l). A calibration curve is prepared by linear regression analysis of iron concentration versus absorbency (at the 372 nm line). Samples and blanks are analyzed at the same instrumental conditions, and iron concentrations are calculated from the linear regression equation.

Calculation

$$\% \text{ Pyritic Sulfur} = \frac{DXV}{W} \times 114.83$$

D = iron in sample - iron in reagent blank (mg/l)
V = final volume of digested sample (liters)
W = sample weight (milligrams)
114.83 = percent atomic weight of iron in pyritic sulfur

3. STANDARD TEST METHOD FOR GROSS CALORIFIC VALUE (Btu) (ASTMD-2015)

Summary of Method

- Calorific value is determined in this method by burning a weighed sample in an adiabatic oxygen bomb calorimeter under controlled conditions. The calorific value is computed from temperature observations made before and after combustion, making proper allowance for thermochemical corrections.

Apparatus

- Calorimeter, adiabatic jacke
- Oxygen Bomb
- Thermometer, traceable to NBS
- Sample Holder
- Programmer (optional)
- Printer (optional)

Reagents and Materials

- Deionized water, reagent grade
- Benzoic acid, NBS certified
- Methyl orange indicator solution
- Oxygen, 99.5% pure
- Sodium carbonate (7.68 g/l)
- Fuse Wire, nickel-chromium alloy, 10 cm lengths

Procedure

- Preparation of the Oxygen Bomb - weight 1 gram ± 0.1 mg of pulverized coal into a tared comb crucible. Attach the fuse wire to the oxygen bomb electrodes, insert the sample crucible, add 1 ml of water to the bomb, assemble bomb cover and charge to 30 atmospheres of oxygen.

- Oxygen Bomb Ignition - place the charged bomb in a stainless steel bucket containing 2000 ± 0.5 g of water. Connect the ignition wires and install the bucket/bomb in the calorimeter. Initiate the 15-minute program cycle by pushing the start button. The program's first five minutes are an equilibrium period during which bucket temperatures are recorded in 30-second intervals. At the five minute mark, the bomb fires automatically. The temperature print-out is suspended or the next three minutes because temperature rises rapidly. Following this three-minute wait period, temperatures are printed at 30-second intervals for the duration of the cycle. During the entire cycle, hot and cold water are added to the jacket automatically to prevent a heat exchange between the bomb and the surrounding jacket. Initial and final temperatures are read from the print-out. The initial temperature is the last recorded temperature before the bomb fires and the final temperature is the highest repeated temperature recorded within the last two minutes of the program.

- Analysis of Bomb Contents - remove the bomb and slowly release the pressure at a uniform rate. Examine the bomb interior and discard the test if unburned sample or sooty deposits are found. Wash the interior of the bomb with distilled water, dilute the washing to 150 ml, and titrate with standard sodium carbonate. Remove and measure the remaining length of fuse wire. Calculate the burnt fuse wire length from the difference between the original and the final lengths.

- Calibration - determine the water equivalent (W) of each calorimeter as the average of a series of ten individual runs of benzoic acid. Prepare a 1 gram ± 0.1 mg pellet of benzoic acid (using a die and press). Ignite and analyze the bomb contents as previously described. The standard deviation of the calculation of W should not exceed 6.5 Btu/°C.

Calculation

- Water equivalent, W - for a series of ten individual benzoic acid ignitions, calculate W using the following formula:

$$W = \frac{(H)\ (g) + e_1 + e_3}{t}$$

W = water equivalent
H = heat of combustion of benzoic acid from National Bureau of Standards Certificate (cal/g)
g = weight of benzoic acid (g)
t = temperature rise (°C)
e_1 = correction for the heat of formation of HNO_3 (ml Na_2CO_3 x 1 cal/ml = cal)
e_3 = correction for heat of combustion of firing wire (2.3 cal/cm)

- Gross Calorific Value, Qv - the gross heat content, in cal/g, is equal to:

$$Qv = \frac{(t)\ (W) - e_1 - e_2 - e_3}{g}$$

Qv = heat content (cal/g)
t = temperature rise (°C)
W = water equivalent (cal/°C)
e_1 = heat of formation of HNO_3 (cal.)
e_2 = correction for heat of formation of H_2SO_4
(% sulfur x 14 x grams sample = cal.)
e_3 = heat of combustion of firing wire (cal.)
g = sample weight (grams)

- Conversion to Btu/lb
  cal/g x 1.8 = Btu/lb

4. STANDARD TEST METHOD FOR ASH IN THE ANALYSIS OF COAL (ASTMD-3174)

Summary of Method

Ash is determined by weighing the residue remaining after burning the coal under rigidly controlled conditions of sample weight, temperature, time and atmosphere.

Apparatus

- Balance, sensitive to 0.1 mg
- Electric muffle furnace - capable of regulated temperatures between 700° and 750°C

Reagents and Materials

- Porcelain capsules, 7/8" (22 mm) in depth, and 1-3/4" (44 mm) in diameter

Procedure

Place the porcelain capsules containing the dried coal from the moisture determination, ASTM-D 3173 (Appendix D), in a coal muffle furnace. Heat gradually so that the temperature reaches 750°C in 4 hours. Transfer the capsule to a dessicator for cooling. Weigh the dish after it has completely cooled.

Calculations

% Ash = (A-B)/C x 100

A = weight of capsule and ash residue (g)
B = weight of empty capsule (g)
C = weight of analysis sample before drying (g)

5. STANDARD TEST METHOD FOR AIR DRY LOSS AND RESIDUAL MOISTURE IN COAL (ASTMD-3173, D-3302)

Summary of Method

- This method is based on the loss in weight of a coal sample in an air atmosphere under rigidly controlled conditions of temperature, time, and air flow.
- Final moisture determination, or residual moisture, is made in a heated forced-air circulation oven under rigidly defined conditions.
- The total moisture is calculated from losses (or gains) in air-drying and the residual moisture determinations.

Apparatus

- Drying area, clean floor or equivalent which allows good air circulation.
- Air drying oven, forced air 10 to 15°C above room temperature.
- Drying oven, forced-draft type 107 ± 3°C.
- Scale, sensitive to 20 g.
- Balance, analytical, sensitive to 0.1 mg.

Reagents and Materials

- Drying Pans, non-corroding.
- Crucibles, low profile, preconditioned at 500°C.
- Dessicator.

Procedure

- Determination of air-dry moisture loss.
  A gross sample of coal is spread onto a tared drying pan. The spreading should be even, with the depth not more than one-half inch, to allow for proper air drying. The gross sample is weighed and allowed to dry for 10 to 18 hours. The coal sample is re-weighed, and the weight loss of the sample is used to determine percent air-dry loss moisture.

- o Determination of residual moisture.
  The gross sample after air-drying is pulverized, split, and seived to pass a 60 mesh (250µ m) screen. A 1.0 gram sample of caol is weighed into a conditioned, tared crucible. The sample is placed into a drying oven at 107°C for 45 minutes. The sample is then cooled in a dessicator for ten minutes and weighed. The percent residual moisture is calculated form the difference in the initial and final weights.

Calculations

o Air-Dry Loss (%)

$$A = \frac{L}{G} \times 100$$

A = % air dry loss
L = Loss in weight after air drying (g)
G = Weight of initial sample (g)

o Residual Moisture (%)

$$R = \frac{(W - H)}{W} \times 100$$

W = Weight of initial sample (g)
H = Weight of sample after heating (g)

o Total Moisture (%)

$$M = \frac{R\ (100 - A)}{100} + A$$

APPENDIX B

RESULTS OF AED PROCESS BENCH-SCALE UNIT TESTS

LIST OF TABLES

The Tables B-1 through B-28 give AED System Results (Two Stages) for the following Coals:

Table	Coal	Page
B-1	B-1	B-4
B-2	B-2	B-5
B-3	B-3(8/11)	B-6
B-4	B-3(11)	B-7
B-5	B-4	B-8
B-6	B-5	B-9
B-7	B-6(UF)	B-10
B-8	B-6(LK)	B-11
B-9	B-7	B-12
B-10	B-8(H)	B-13
B-11	B-8(V)	B-14
B-12	B-9	B-15
B-13	R-1	B-16
B-14	R-2	B-17
B-15	R-3	B-18
B-16	R-4	B-19
B-17	R-5	B-20
B-18	R-6	B-21
B-19	R-7	B-22
B-20	R-8	B-23
B-21	R-9	B-24

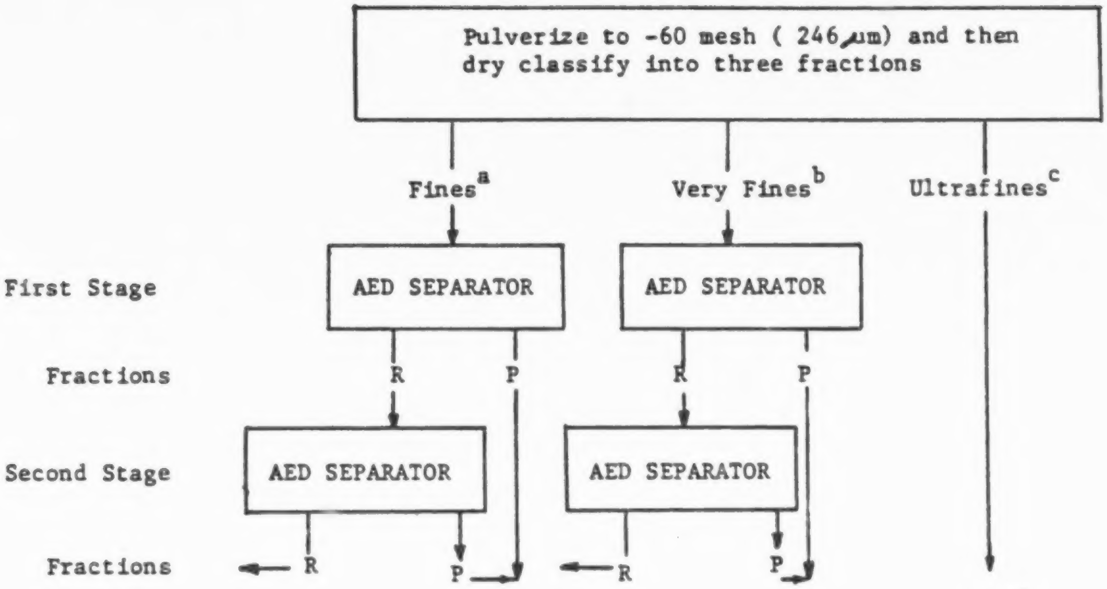
Table	Coal	Page
B-22	G-1	B-25
B-23	G-2	B-26
B-24	G-3	B-27
B-25	G-4	B-28
B-26	G-5	B-29
B-27	G-6	B-30
B-28	S-1	B-31

TABLE B-1

AED SYSTEM RESULTS, TWO STAGES

COAL: B-1

wt. % S	3.93
wt. % Ash	14.36
BTU/lb	12,600


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines	Very Fines	Ultrafines
wt. % S	2.67	2.86	3.08
wt. % Ash	8.2	16.35	18.97
BTU/lb.	13,640	12,300	11,800
yield by weight	65	16	6
yield by BTU	70	16	5

Total Products

wt. % S	2.73
wt. % Ash	10.4
BTU/lb.	13,270
yield by weight	86
yield by BTU	91

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

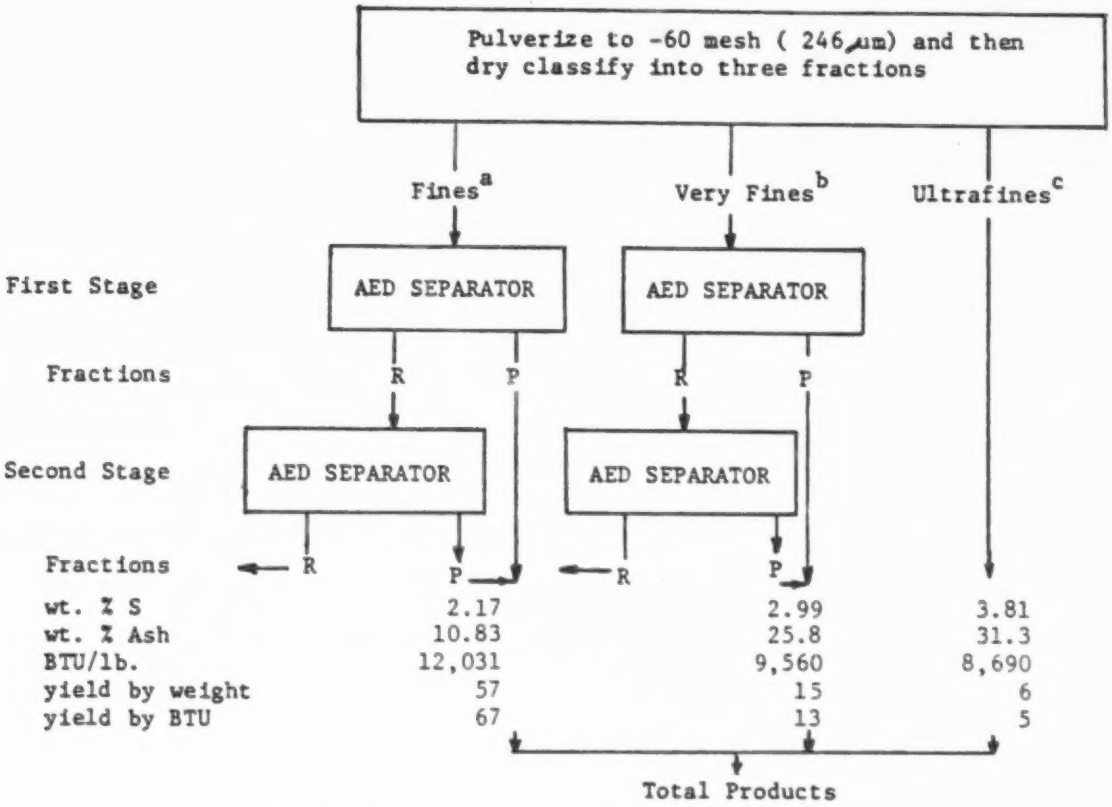
c - Ultrafines are - 20 µm

NOTE: R = Rejects
P = Products

TABLE B-2

AED SYSTEM RESULTS, TWO STAGES
COAL: B-2

wt. % S	2.70
wt. % Ash	22.6
BTU/lb	10,250


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Total Products

	Fines P	Very Fines P	Ultrafines
wt. % S	2.17	2.99	3.81
wt. % Ash	10.83	25.8	31.3
BTU/lb.	12,031	9,560	8,690
yield by weight	57	15	6
yield by BTU	67	13	5

Total Products

wt. % S	2.44
wt. % Ash	13.6
BTU/lb.	11,310
yield by weight	78
yield by BTU	86

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

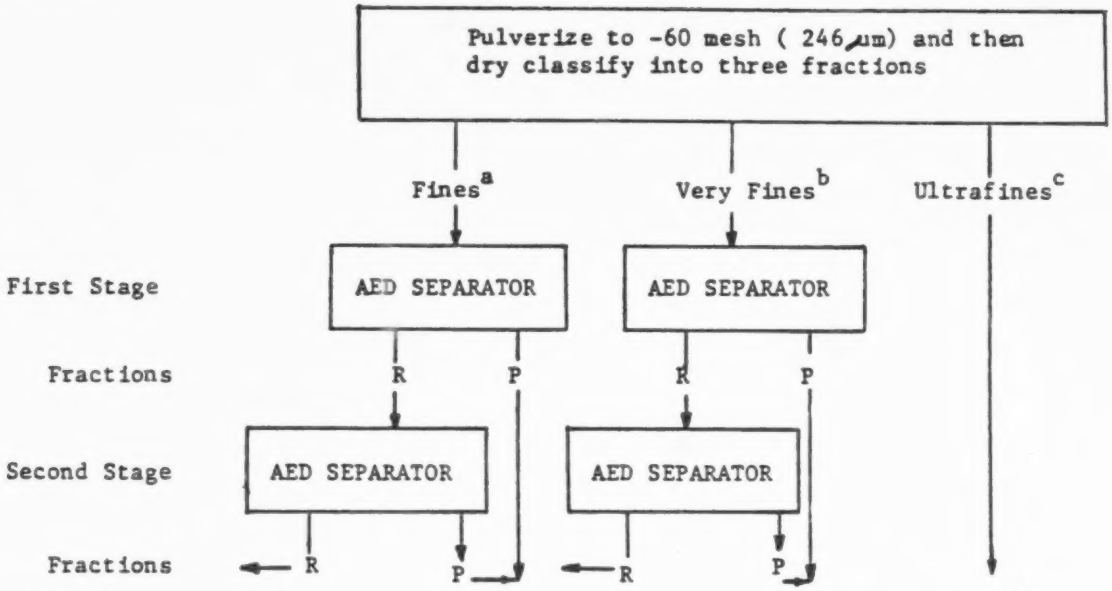
c - Ultrafines are - 20 µm

NOTE: R = Rejects
P = Products

TABLE B-3

AED SYSTEM RESULTS, TWO STAGES
COAL: B-3 (8/11)

wt. % S	3.49
wt. % Ash	19.5
BTU/lb	11,084


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

wt. % S	2.50	3.03	3.29
wt. % Ash	13.7	25.4	27.7
BTU/lb.	12,203	10,252	9,570
yield by weight	63	18	6
yield by BTU	70	17	5

Total Products

wt. % S	2.66
wt. % Ash	17.0
BTU/lb.	11,616
yield by weight	87
yield by BTU	92

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

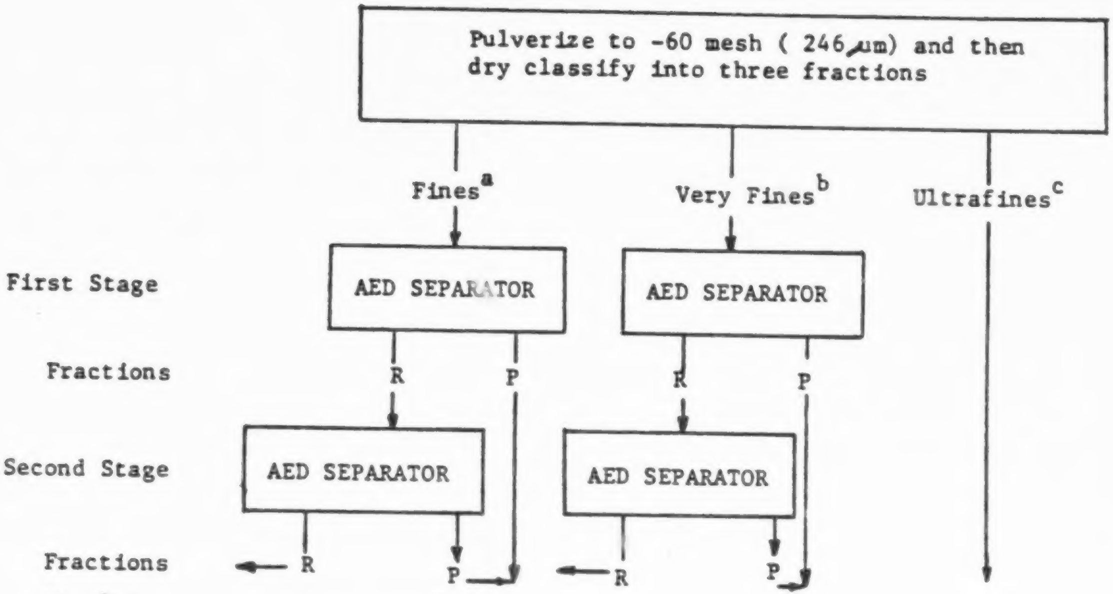
NOTE: R = Rejects
P = Products

TABLE B-4

AED SYSTEM RESULTS, TWO STAGES

COAL: B-3 (11)

wt. % S	2.21
wt. % Ash	20.0
BTU/lb	11,131


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines	Very Fines	Ultrafines
wt. % S	1.61	2.07	2.32
wt. % Ash	13.3	22.8	26.3
BTU/lb.	12,130	10,848	10,117
yield by weight	62	16	8
yield by BTU	67	16	7

	Total Products
wt. % S	1.76
wt. % Ash	16.4
BTU/lb.	11,708
yield by weight	85
yield by BTU	90

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

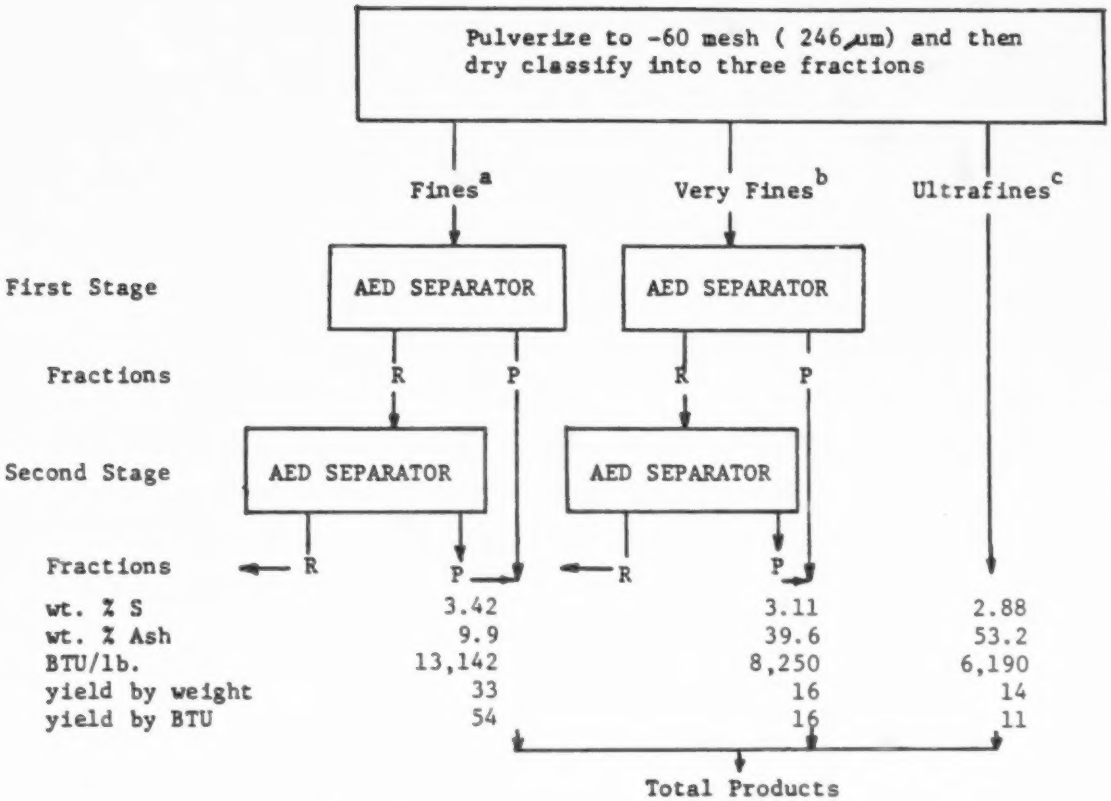
NOTE: R = Rejects
P = Products

TABLE B-5

AED SYSTEM RESULTS, TWO STAGES

COAL: B-4

wt. % S	4.02
wt. % Ash	38.7
BTU/lb	8,070


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Total Products

Fractions	Fines P	Very Fines P	Ultrafines
wt. % S	3.42	3.11	2.88
wt. % Ash	9.9	39.6	53.2
BTU/lb.	13,142	8,250	6,190
yield by weight	33	16	14
yield by BTU	54	16	11

Total Products

wt. % S	3.22
wt. % Ash	26.9
BTU/lb.	10,342
yield by weight	63
yield by BTU	81

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

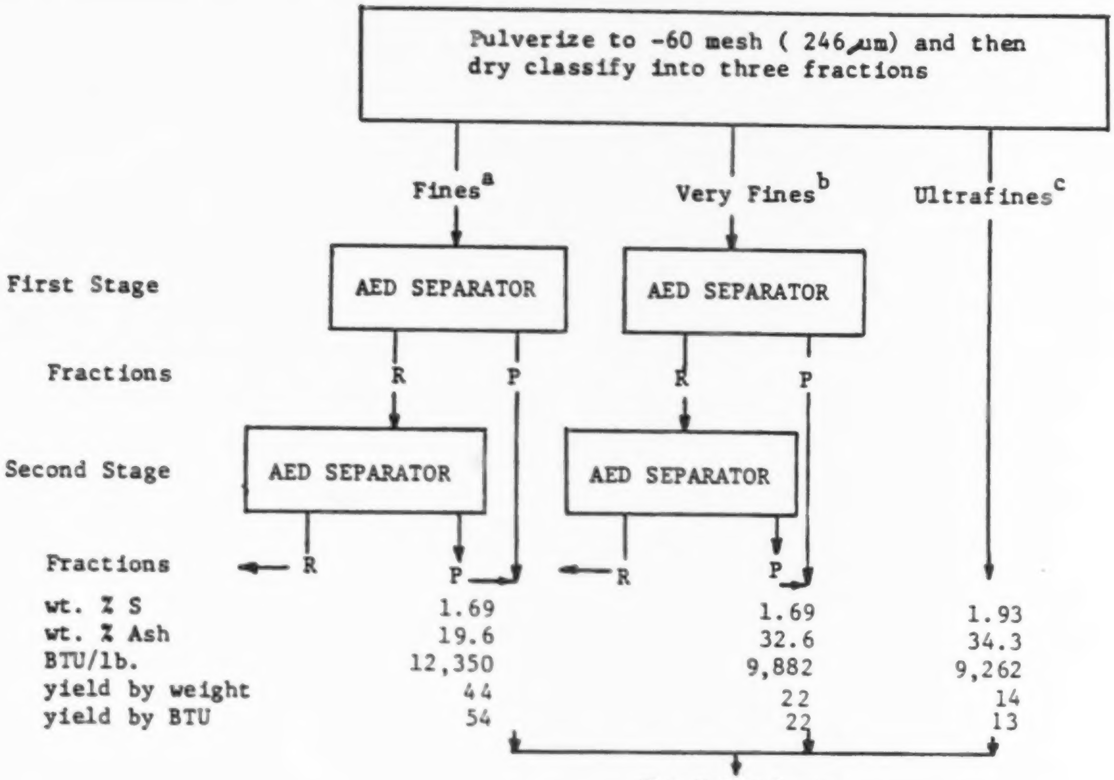
NOTE: R = Rejects
P = Products

TABLE B-6

AED SYSTEM RESULTS, TWO STAGES

COAL: B-5

wt. % S	2.24
wt. % Ash	32.0
BTU/lb	10,007


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines	Very Fines	Ultrafines
wt. % S	1.69	1.69	1.93
wt. % Ash	19.6	32.6	34.3
BTU/lb.	12,350	9,882	9,262
yield by weight	44	22	14
yield by BTU	54	22	13

	Total Products
wt. % S	1.72
wt. % Ash	25.6
BTU/lb.	11,128
yield by weight	80
yield by BTU	89

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

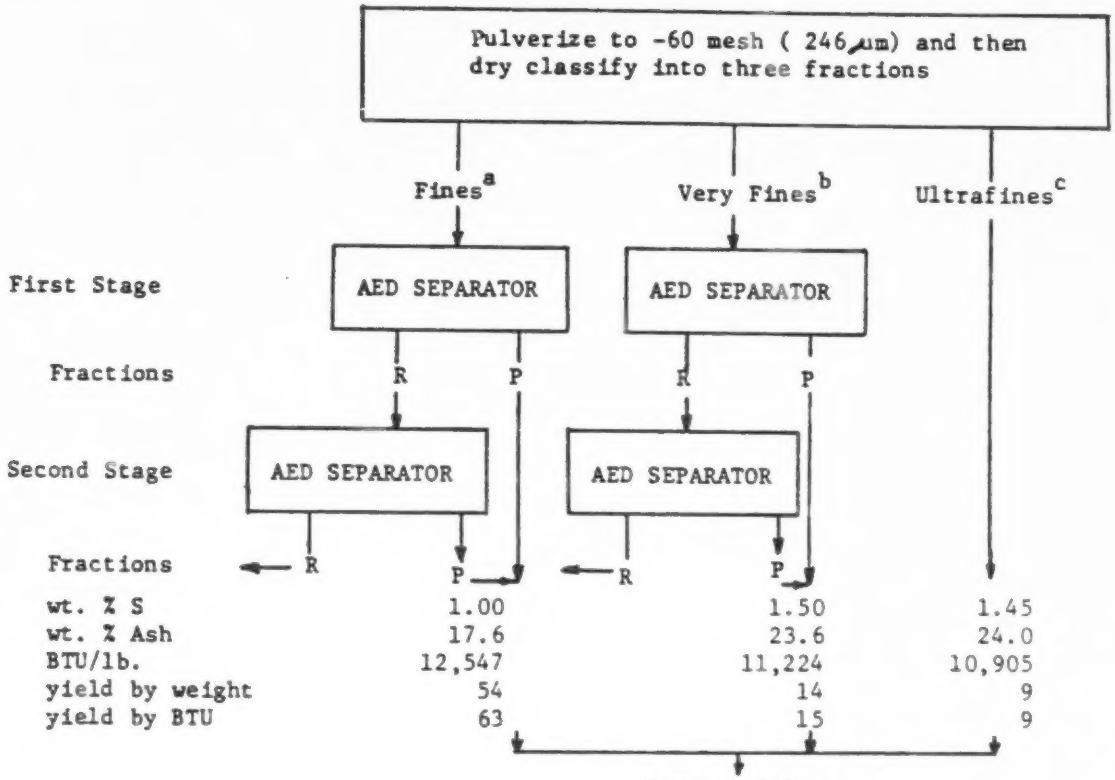
NOTE: R = Rejects
P = Products

TABLE B-7

AED SYSTEM RESULTS, TWO STAGES

COAL: B-6 (UF)

wt. % S	1.47
wt. % Ash	26.0
BTU/lb	10,829


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Total Products

	Fines	Very Fines	Ultrafines
wt. % S	1.00	1.50	1.45
wt. % Ash	17.6	23.6	24.0
BTU/lb.	12,547	11,224	10,905
yield by weight	54	14	9
yield by BTU	63	15	9

Total Products

wt. % S	1.15
wt. % Ash	19.4
BTU/lb.	12,115
yield by weight	77
yield by BTU	87

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

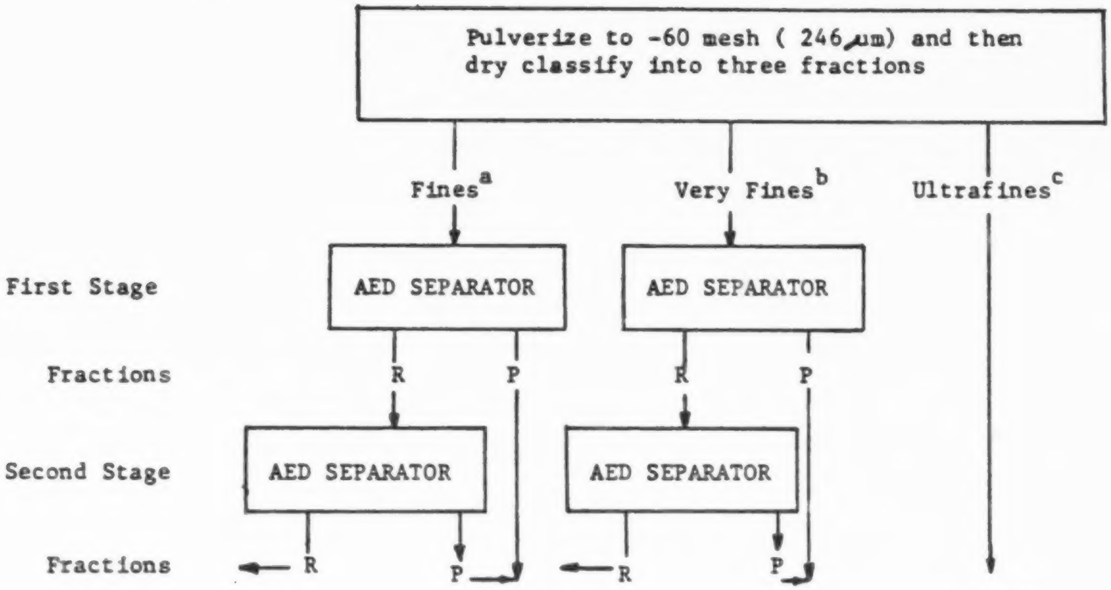
NOTE: R = Rejects
P = Products

TABLE B-8

AED SYSTEM RESULTS, TWO STAGES

COAL: B-6 (LK)

wt. % S	3.99
wt. % Ash	23.1
BTU/lb	11,541


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines	Very Fines	Ultrafines
wt. % S	2.29	3.45	4.09
wt. % Ash	21.2	24.0	23.7
BTU/lb.	12,471	11,408	11,280
yield by weight	53	20	17
yield by BTU	57	20	17

Total Products

wt. % S	2.91
wt. % Ash	21.6
BTU/lb.	12,008
yield by weight	90
yield by BTU	93

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

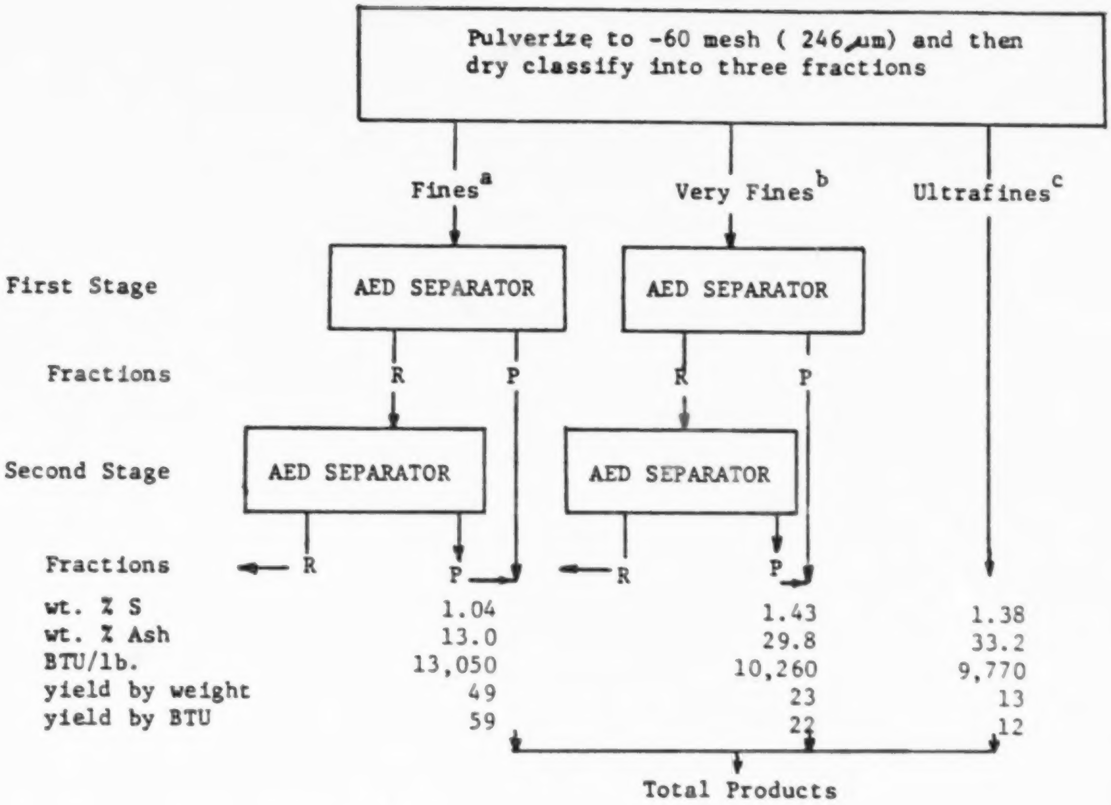
NOTE: R = Rejects
P = Products

TABLE B-9

AED SYSTEM RESULTS, TWO STAGES

COAL: B-7

wt. % S	1.96
wt. % Ash	27.8
BTU/lb	10,710


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Total Products

	Fines	Very Fines	Ultrafines
wt. % S	1.04	1.43	1.38
wt. % Ash	13.0	29.8	33.2
BTU/lb.	13,050	10,260	9,770
yield by weight	49	23	13
yield by BTU	59	22	12

Total Products

wt. % S	1.20
wt. % Ash	21.2
BTU/lb.	11,790
yield by weight	84
yield by BTU	93

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

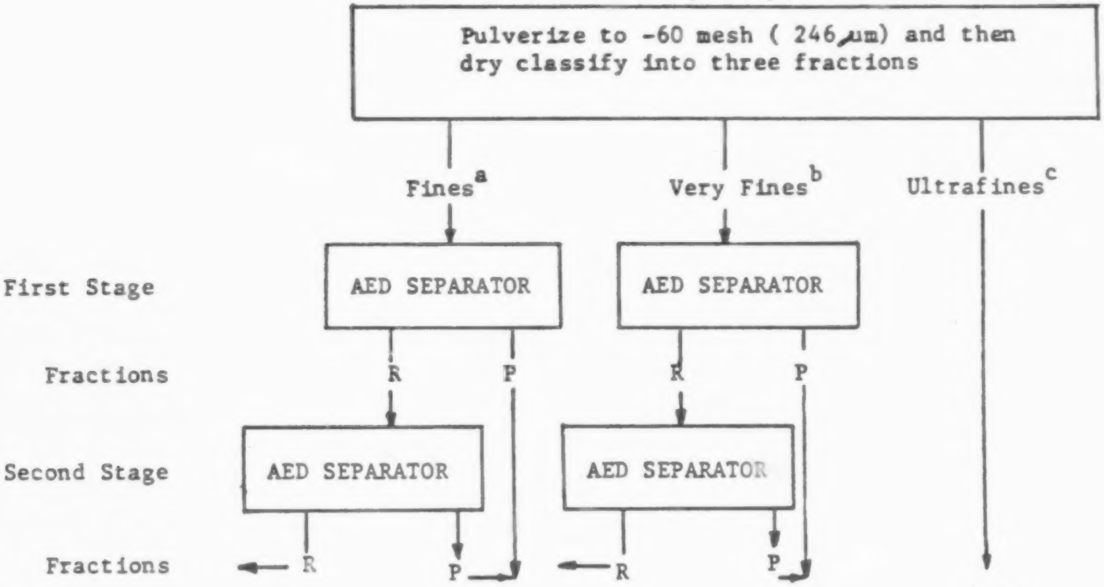
NOTE: R = Rejects
P = Products

TABLE B-10

AED SYSTEM RESULTS, TWO STAGES

COAL: B-8 (H)

wt. % S	4.04
wt. % Ash	31.5
BTU/lb	10,171


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines	Very Fines	Ultrafines
wt. % S	2.24	2.69	2.40
wt. % Ash	13.5	25.1	30.3
BTU/lb.	13,480	11,415	10,113
yield by weight	41	27	6
yield by BTU	55	30	6

Total Products

wt. % S	2.58
wt. % Ash	18.7
BTU/lb.	12,468
yield by weight	74
yield by BTU	90

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

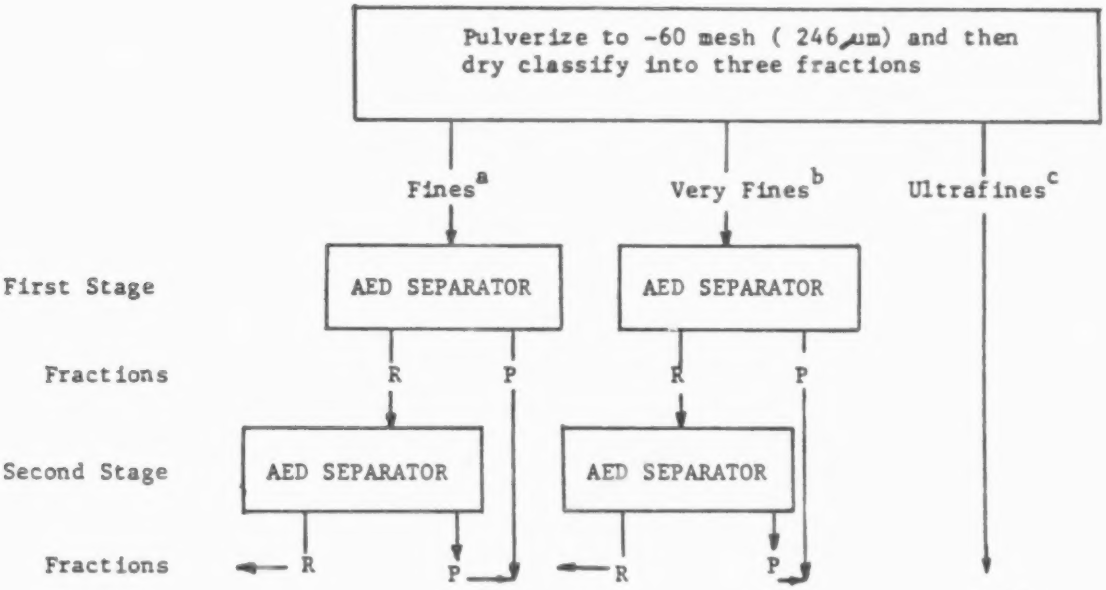
c - Ultrafines are - 20 µm

NOTE: R = Rejects
P = Products

TABLE B-11

AED SYSTEM RESULTS, TWO STAGES
COAL: B-8 (V)

wt. % S	1.84
wt. % Ash	24.8
BTU/lb	11,290


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

wt. % S	1.17	1.49	1.59
wt. % Ash	14.0	21.3	24.9
BTU/lb.	12,718	11,824	11,305
yield by weight	51	23	9
yield by BTU	57	24	9

	Total Products
wt. % S	1.31
wt. % Ash	17.2
BTU/lb.	12,319
yield by weight	82
yield by BTU	90

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

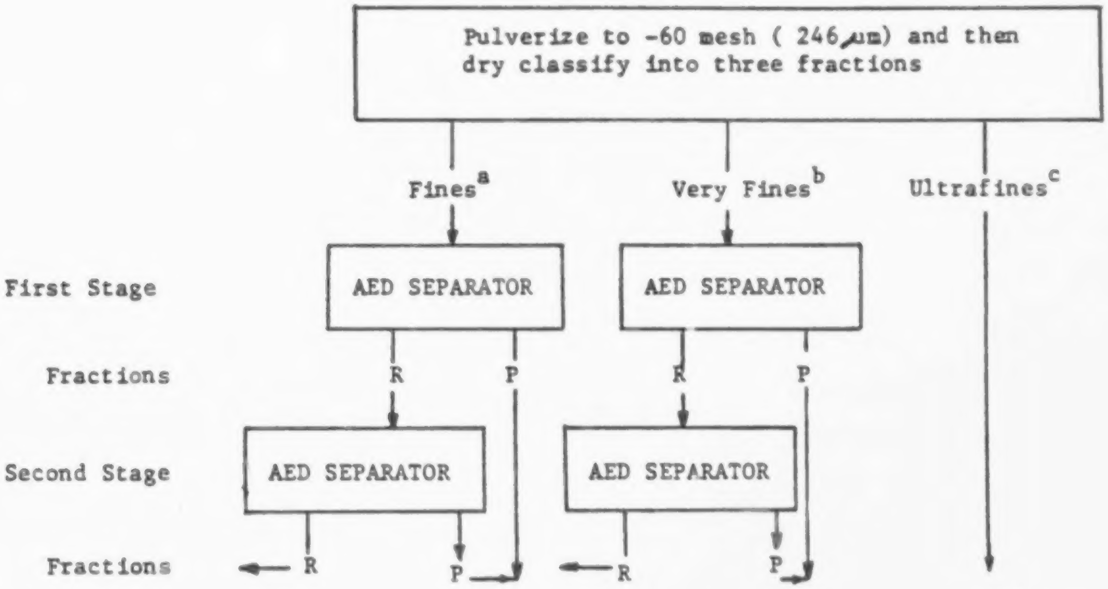
NOTE: R = Rejects
P = Products

TABLE B-12

AED SYSTEM RESULTS, TWO STAGES

COAL: B-9

wt. % S	1.79
wt. % Ash	30.0
BTU/lb	10,336


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines	Very Fines	Ultrafines
wt. % S	1.31	1.35	1.28
wt. % Ash	21.6	25.4	26.6
BTU/lb.	11,984	11,042	11,010
yield by weight	49	19	19
yield by BTU	57	21	10

Total Products

wt. % S	1.31
wt. % Ash	23.3
BTU/lb.	11,631
yield by weight	78
yield by BTU	87

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

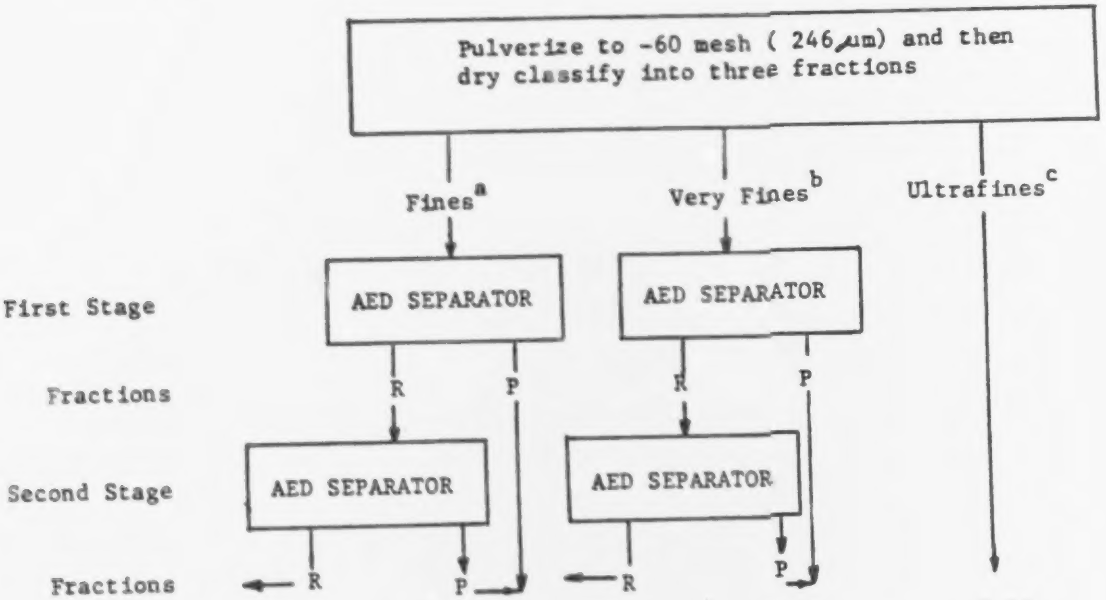
NOTE: R = Rejects
P = Products

TABLE B-13

AED SYSTEM RESULTS, TWO STAGES

COAL: R-1

wt. % S	0.86
wt. % Ash	34.1
BTU/lb	9,207


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

wt. % S	0.78	0.84	0.80
wt. % Ash	10.4	40.4	44.8
BTU/lb.	12,998	8,426	7,464
yield by weight	42	17	11
yield by BTU	59	15	9

Total Products

wt. % S	0.81
wt. % Ash	23.2
BTU/lb.	11,034
yield by weight	70
yield by BTU	83

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

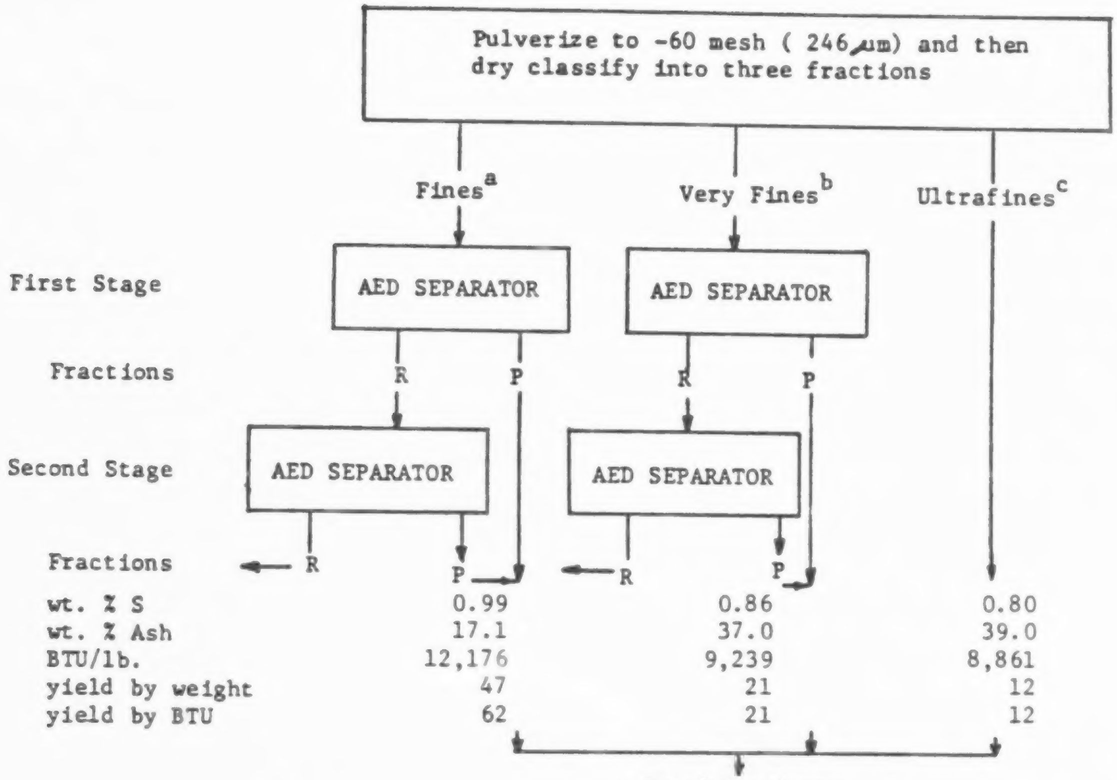
NOTE: R = Rejects
P = Products

TABLE B-14

AED SYSTEM RESULTS, TWO STAGES

COAL: R-2

wt. % S	0.96
wt. % Ash	34.4
BTU/lb	9,292


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines	Very Fines	Ultrafines
wt. % S	0.99	0.86	0.80
wt. % Ash	17.1	37.0	39.0
BTU/lb.	12,176	9,239	8,861
yield by weight	47	21	12
yield by BTU	62	21	12

	Total Products
wt. % S	0.93
wt. % Ash	26.2
BTU/lb.	10,898
yield by weight	81
yield by BTU	95

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

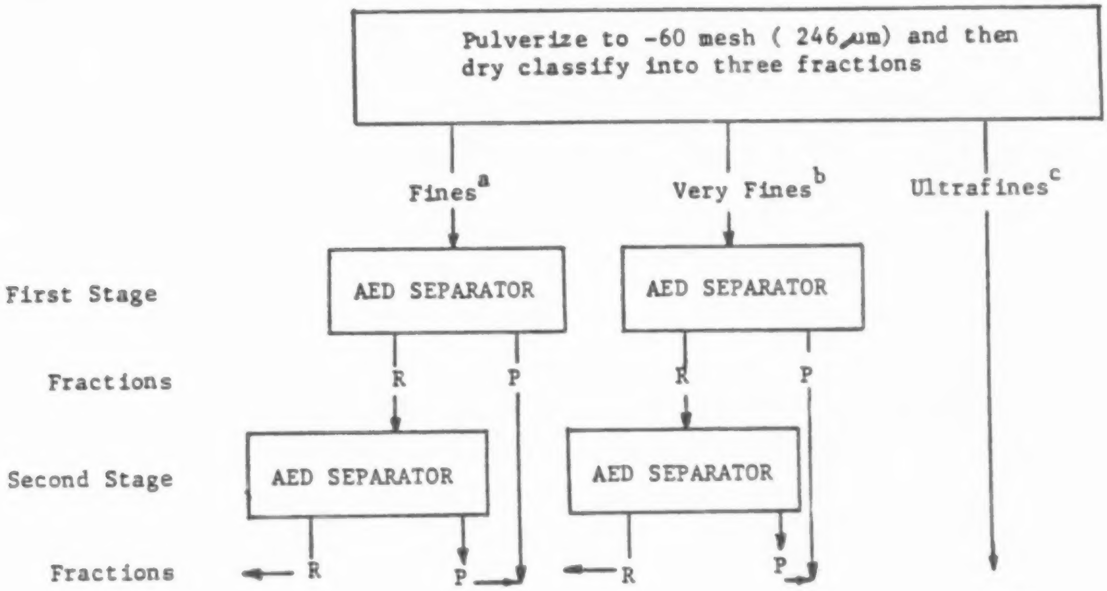
NOTE: R = Rejects
P = Products

TABLE B-15

AED SYSTEM RESULTS, TWO STAGES

COAL: R-3

wt. % S	3.74
wt. % Ash	31.0
BTU/lb	8,870



Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

wt. % S	3.16	3.23	3.53
wt. % Ash	10.2	33.7	45.0
BTU/lb.	12,728	8,868	7,502
yield by weight	46	12	15
yield by BTU	66	12	13

Total Products

wt. % S	3.25
wt. % Ash	20.9
BTU/lb.	11,021
yield by weight	73
yield by BTU	91

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

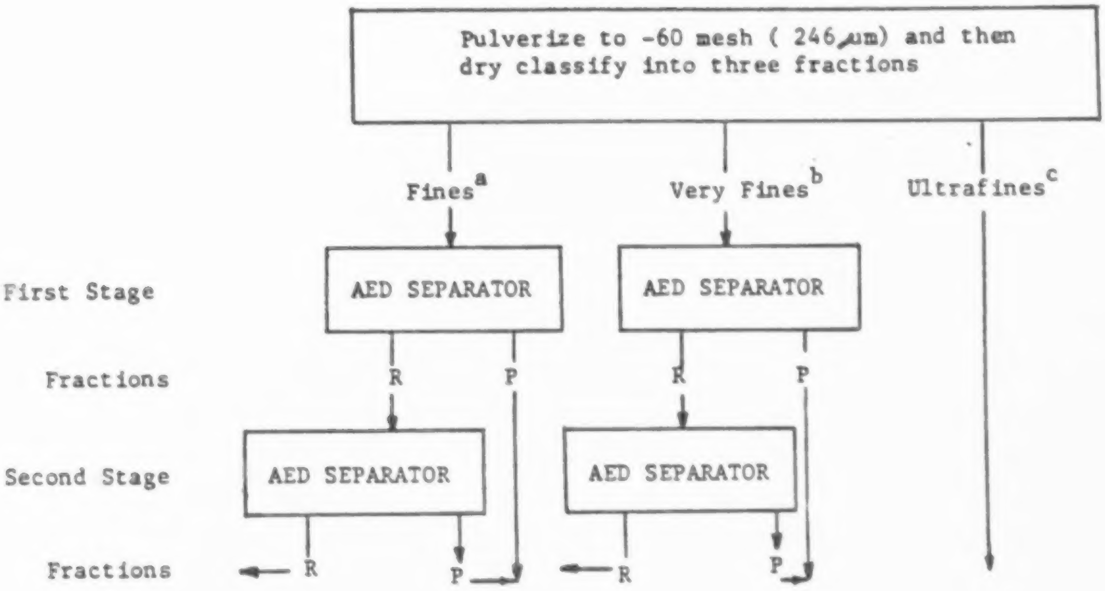
NOTE: R = Rejects
P = Products

TABLE B-16

AED SYSTEM RESULTS, TWO STAGES

COAL: R-4

wt. % S	1.42
wt. % Ash	18.9
BTU/lb	10,511


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines	Very Fines	Ultrafines
wt. % S	1.41	1.48	1.55
wt. % Ash	7.5	21.2	36.2
BTU/lb.	12,486	10,613	8,231
yield by weight	53	17	12
yield by BTU	63	18	10

Total Products

wt. % S	1.45
wt. % Ash	10.3
BTU/lb.	11,460
yield by weight	83
yield by BTU	90

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

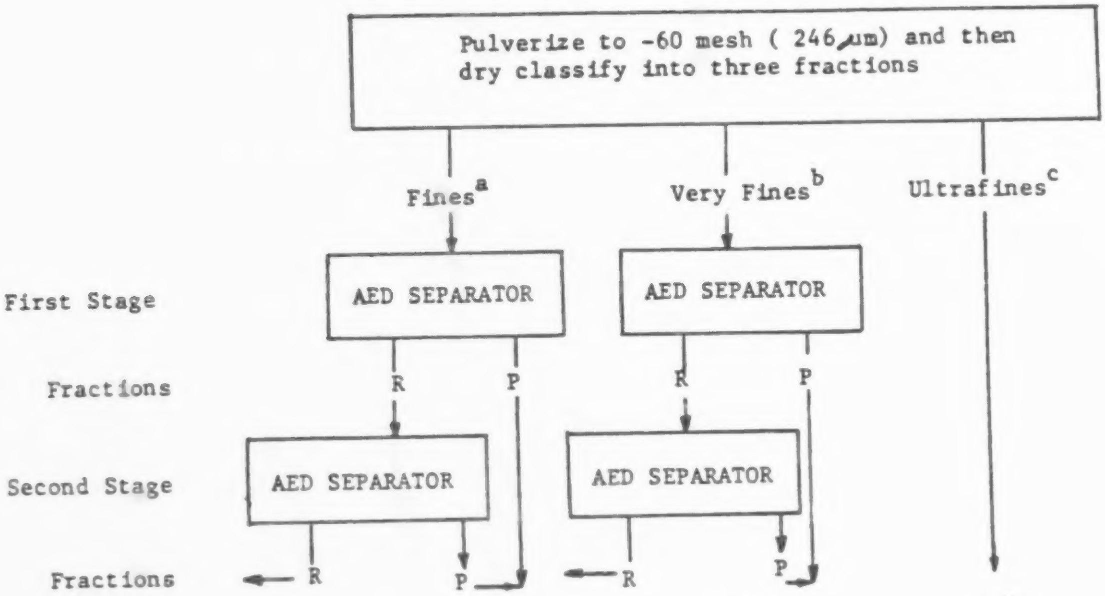
NOTE: R = Rejects
P = Products

TABLE B-17

AED SYSTEM RESULTS, TWO STAGES

COAL: R-5

wt. % S	0.83
wt. % Ash	23.3
BTU/lb	10,114


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

wt. % S	0.76	0.73	0.79
wt. % Ash	8.8	25.9	36.1
BTU/lb.	12,607	9,972	7,373
yield by weight	48	13	16
yield by BTU	59	12	12

Total Products

wt. % S	0.76
wt. % Ash	17.2
BTU/lb.	11,475
yield by weight	76
yield by BTU	86

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

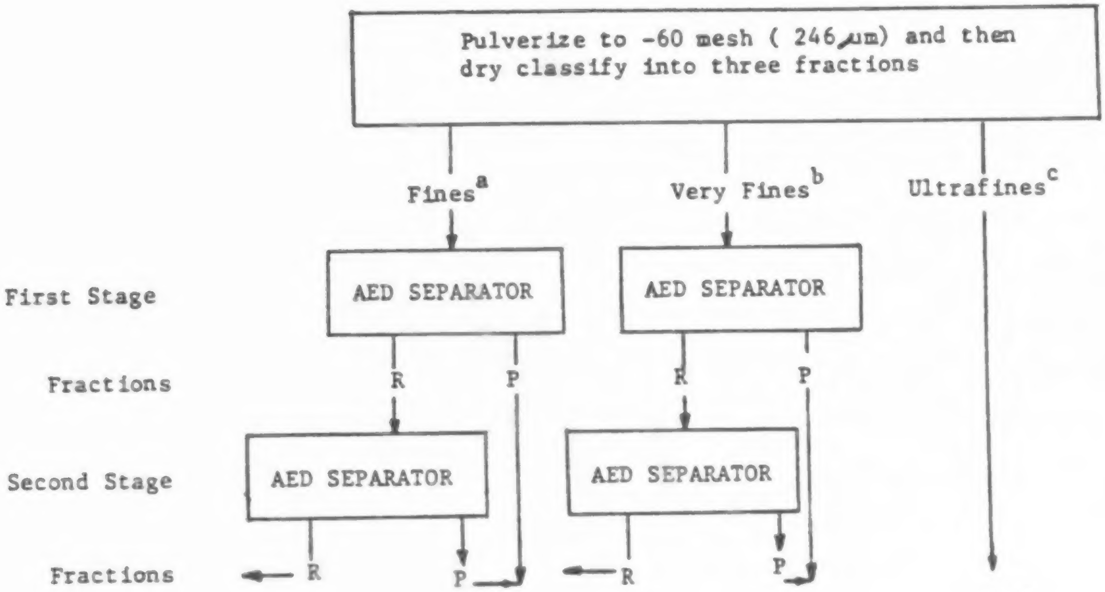
NOTE: R = Rejects
P = Products

TABLE B-18

AED SYSTEM RESULTS, TWO STAGES

COAL: R-6

wt. % S	3.54
wt. % Ash	23.2
BTU/lb	10,528


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

Fractions	P	P	
wt. % S	2.53	2.71	2.97
wt. % Ash	10.1	26.4	31.2
BTU/lb.	12,566	10,158	8,925
yield by weight	55	19	6
yield by BTU	66	18	5

Total Products

wt. % S	2.60
wt. % Ash	14.1
BTU/lb.	11,732
yield by weight	80
yield by BTU	89

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

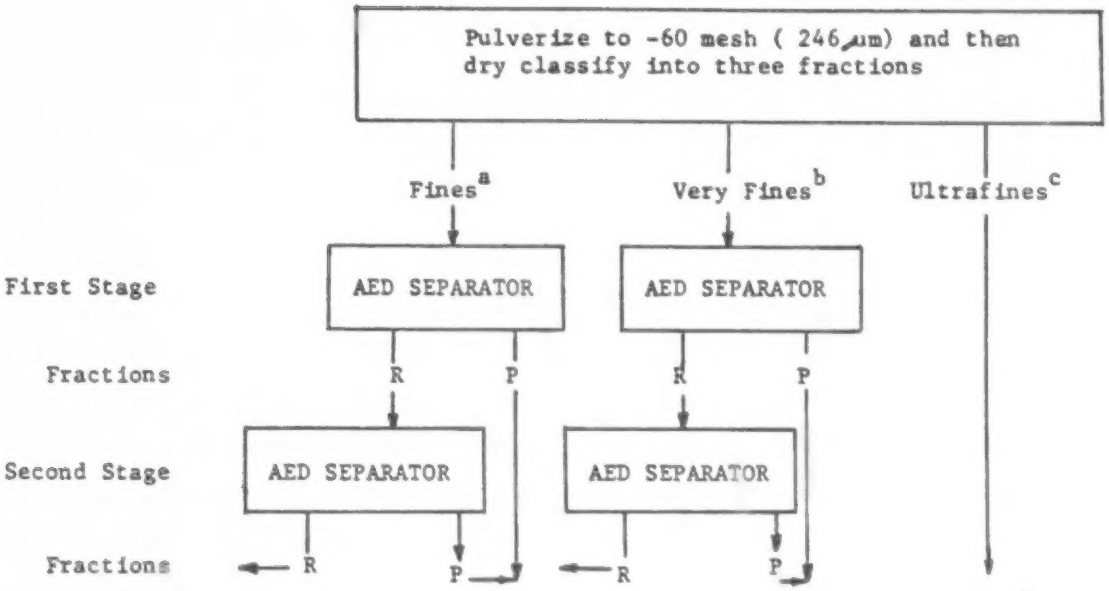
NOTE: R = Rejects
P = Products

TABLE B-19

AED SYSTEM RESULTS, TWO STAGES

COAL: R-7

wt. % S	4.15
wt. % Ash	22.7
BTU/lb	9,875


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

wt. % S	3.17	4.00	4.07
wt. % Ash	9.8	27.0	32.8
BTU/lb.	12,208	9,658	8,626
yield by weight	56	13	6
yield by BTU	69	12	5

Total Products

wt. % S	3.39
wt. % Ash	14.9
BTU/lb.	11,485
yield by weight	75
yield by BTU	87

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

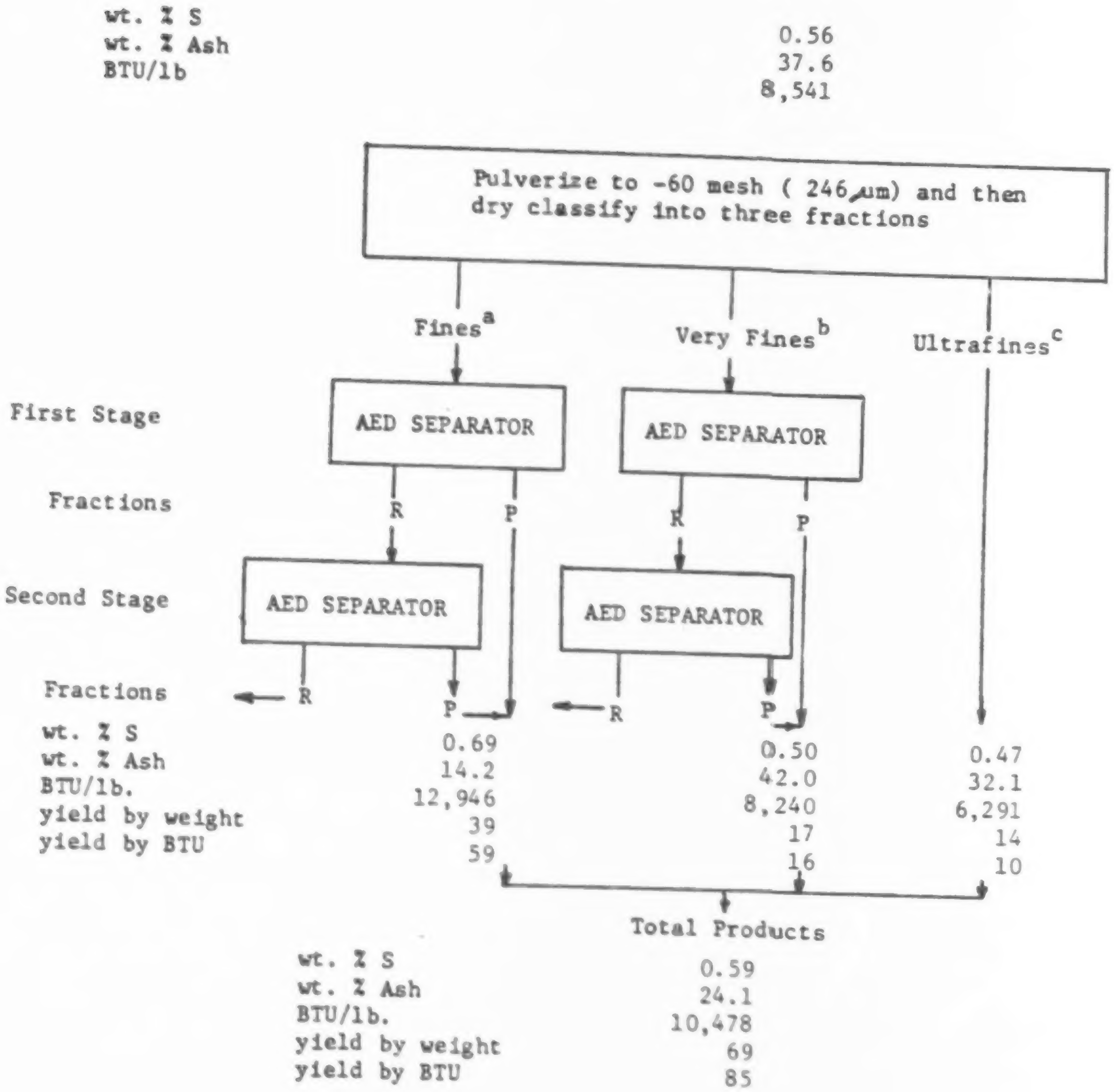
c - Ultrafines are - 20 µm

NOTE: R = Rejects
P = Products

TABLE B-20

AED SYSTEM RESULTS, TWO STAGES

COAL: R-8


wt. % S
wt. % Ash
BTU/lb
0.56
37.6
8,541
Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
wt. % S
wt. % Ash
BTU/lb.
yield by weight
yield by BTU
0.69
14.2
12,946
39
59
0.50
42.0
8,240
17
16
0.47
32.1
6,291
14
10
Total Products
wt. % S
wt. % Ash
BTU/lb.
yield by weight
yield by BTU
0.59
24.1
10,478
69
85

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

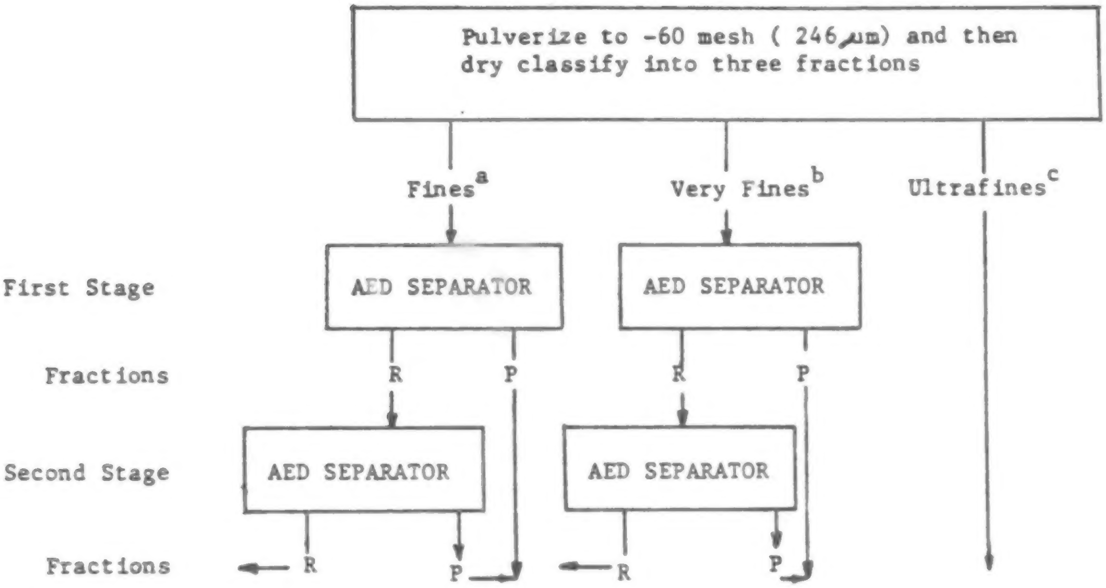
c - Ultrafines are - 20 µm

NOTE: R = Rejects
P = Products

TABLE B-21

AED SYSTEM RESULTS, TWO STAGES
COAL: R-9

wt. % S	0.56
wt. % Ash	25.5
BTU/lb	11,592


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines	Very Fines	Ultrafines
wt. % S	0.59	0.55	0.55
wt. % Ash	12.1	24.7	25.9
BTU/lb.	13,507	11,768	11,249
yield by weight	48	22	11
yield by BTU	56	22	11

Total Products

wt. % S	0.57
wt. % Ash	17.8
BTU/lb.	12,721
yield by weight	81
yield by BTU	89

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

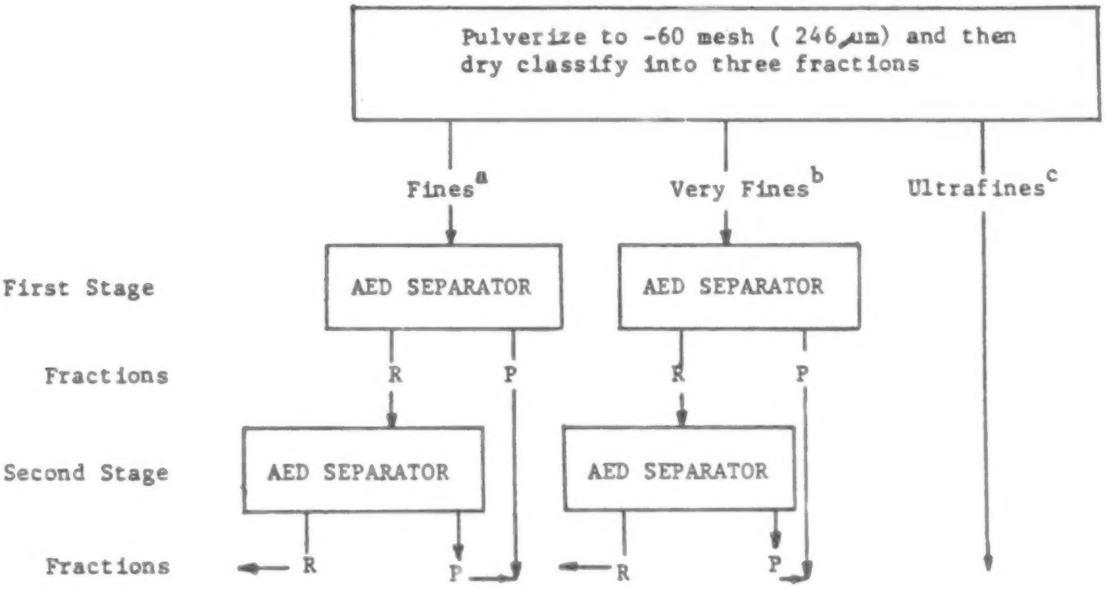
NOTE: R = Rejects
P = Products

TABLE B-22

AED SYSTEM RESULTS, TWO STAGES

COAL: G-1

wt. % S	4.69
wt. % Ash	35.1
BTU/lb	8,981


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

Fractions	Fines P	Very Fines P	Ultrafines
wt. % S	3.20	4.31	4.56
wt. % Ash	11.0	38.1	46.9
BTU/lb.	13,282	8,646	6,997
yield by weight	41	18	12
yield by BTU	60	17	10

Total Products

wt. % S	3.72
wt. % Ash	24.1
BTU/lb.	11,009
yield by weight	71
yield by BTU	87

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

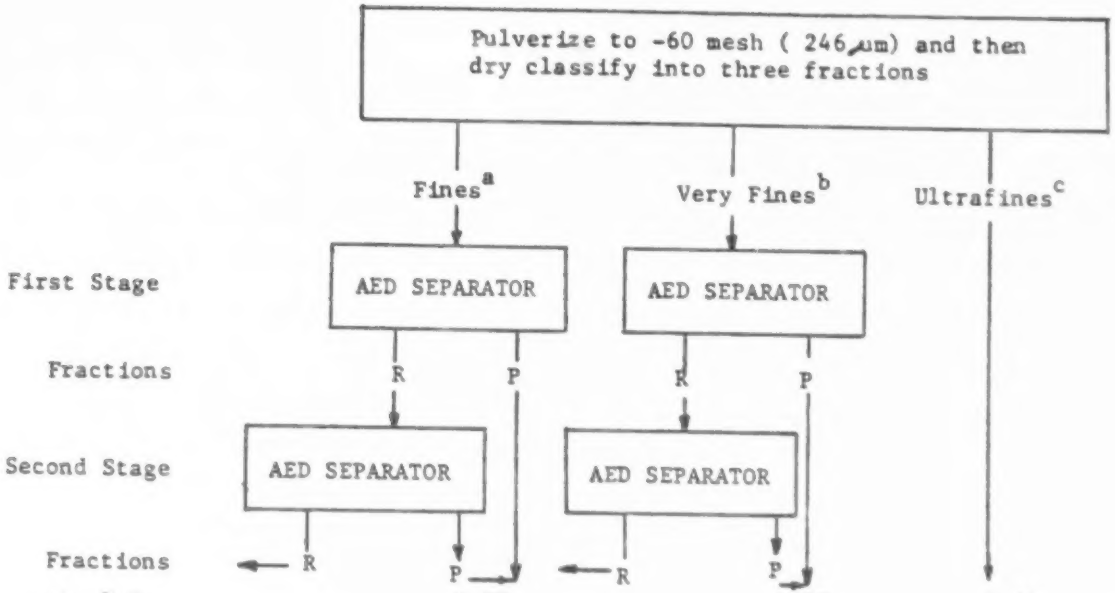
NOTE: R = Rejects
P = Products

TABLE B-23

AED SYSTEM RESULTS, TWO STAGES

COAL: G-2

wt. % S	6.90
wt. % Ash	23.3
BTU/lb	10,151


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

wt. % S	3.57	4.35	5.63
wt. % Ash	8.4	26.3	32.2
BTU/lb.	12,513	10,122	8,940
yield by weight	52	22	8
yield by BTU	64	22	7

Total Products

wt. % S	3.96
wt. % Ash	15.0
BTU/lb.	11,526
yield by weight	82
yield by BTU	93

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

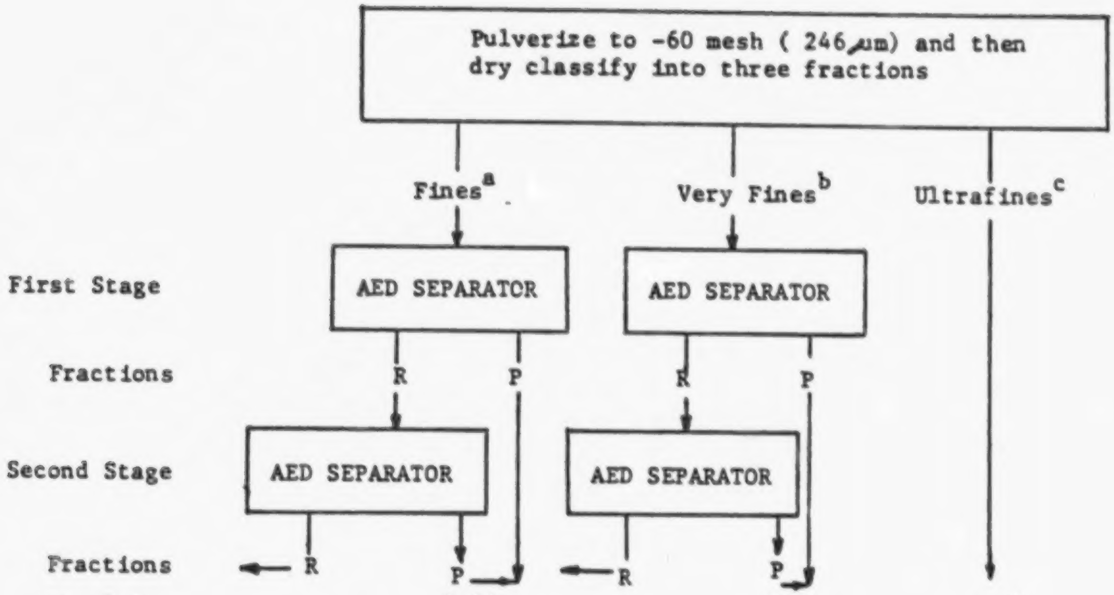
NOTE: R = Rejects
P = Products

TABLE B-24

AED SYSTEM RESULTS, TWO STAGES

COAL: G-3

wt. % S	4.61
wt. % Ash	24.2
BTU/lb	9,615


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

Fractions	P	P	
wt. % S	3.23	3.09	4.63
wt. % Ash	9.6	31.9	38.2
BTU/lb.	12,368	9,053	8,031
yield by weight	54	16	12
yield by BTU	70	15	10

	Total Products
wt. % S	3.41
wt. % Ash	13.2
BTU/lb.	11,096
yield by weight	82
yield by BTU	95

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

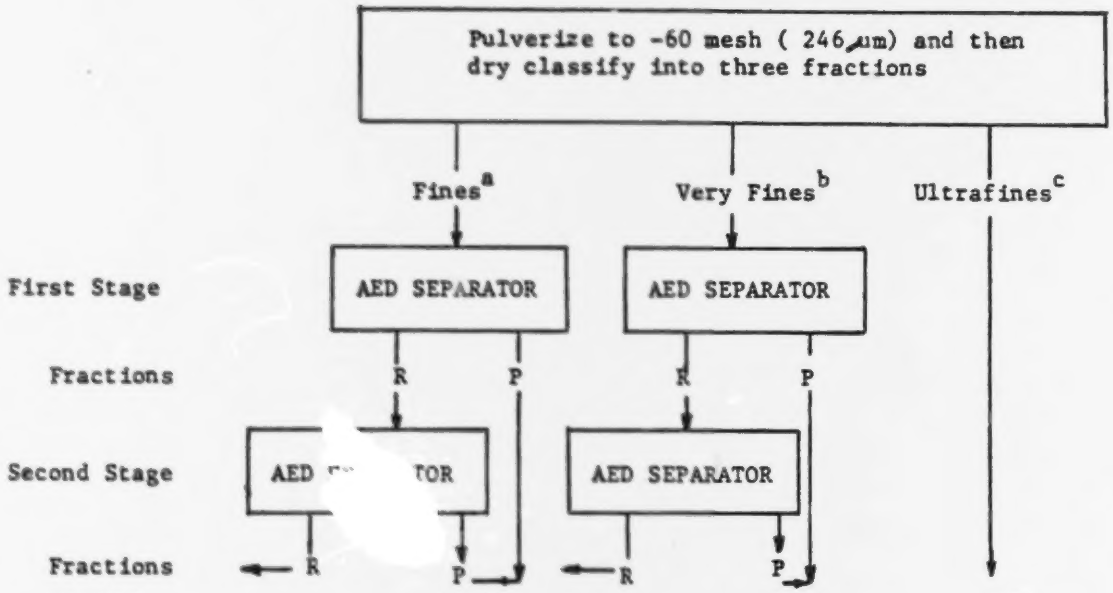
NOTE: R = Rejects
P = Products

TABLE B-25

AED SYSTEM RESULTS, TWO STAGES

COAL: G-4

wt. % S	3.89
wt. % Ash	35.6
BTU/lb	8,020


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED [illegible]TOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines	Very Fines	Ultrafines
wt. % S	2.91	3.04	3.61
wt. % Ash	13.9	41.7	49.9
BTU/lb.	11,625	7,496	5,745
yield by weight	46	18	12
yield by BTU	67	17	8

Total Products

wt. % S	3.05
wt. % Ash	25.9
BTU/lb.	9,745
yield by weight	76
yield by BTU	92

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

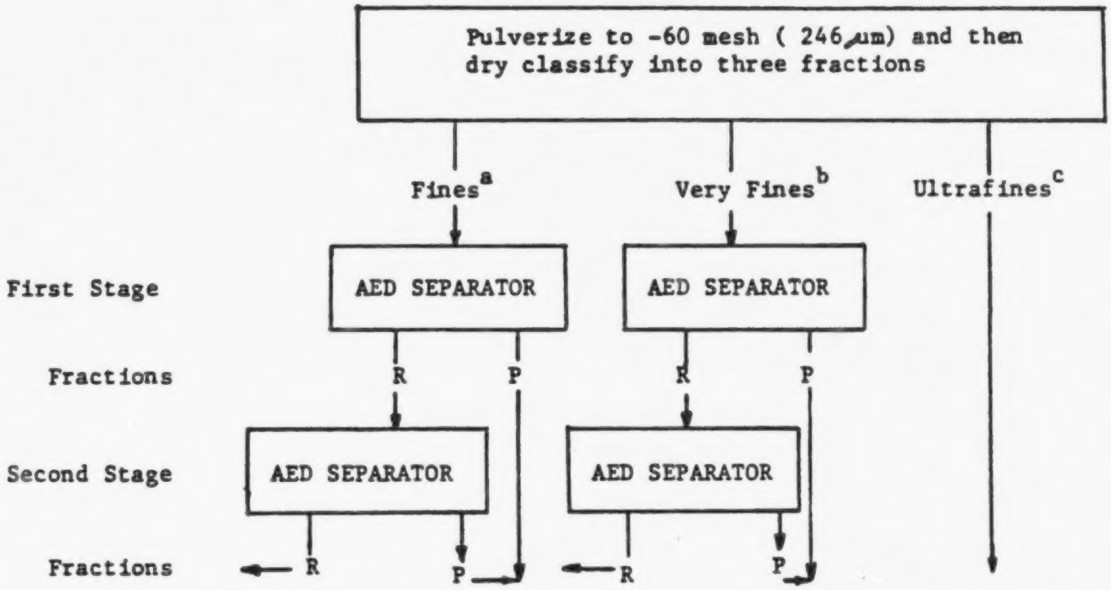
NOTE: R = Rejects
P = Products

TABLE B-26

AED SYSTEM RESULTS, TWO STAGES

COAL: G-5

wt. % S	2.93
wt. % Ash	39.8
BTU/lb	7,576


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

wt. % S	2.26	2.09	2.39
wt. % Ash	13.3	44.7	51.3
BTU/lb.	12,001	7,293	6,493
yield by weight	38	17	18
yield by BTU	60	16	16

Total Products

wt. % S	2.25
wt. % Ash	30.2
BTU/lb.	8,807
yield by weight	73
yield by BTU	85

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

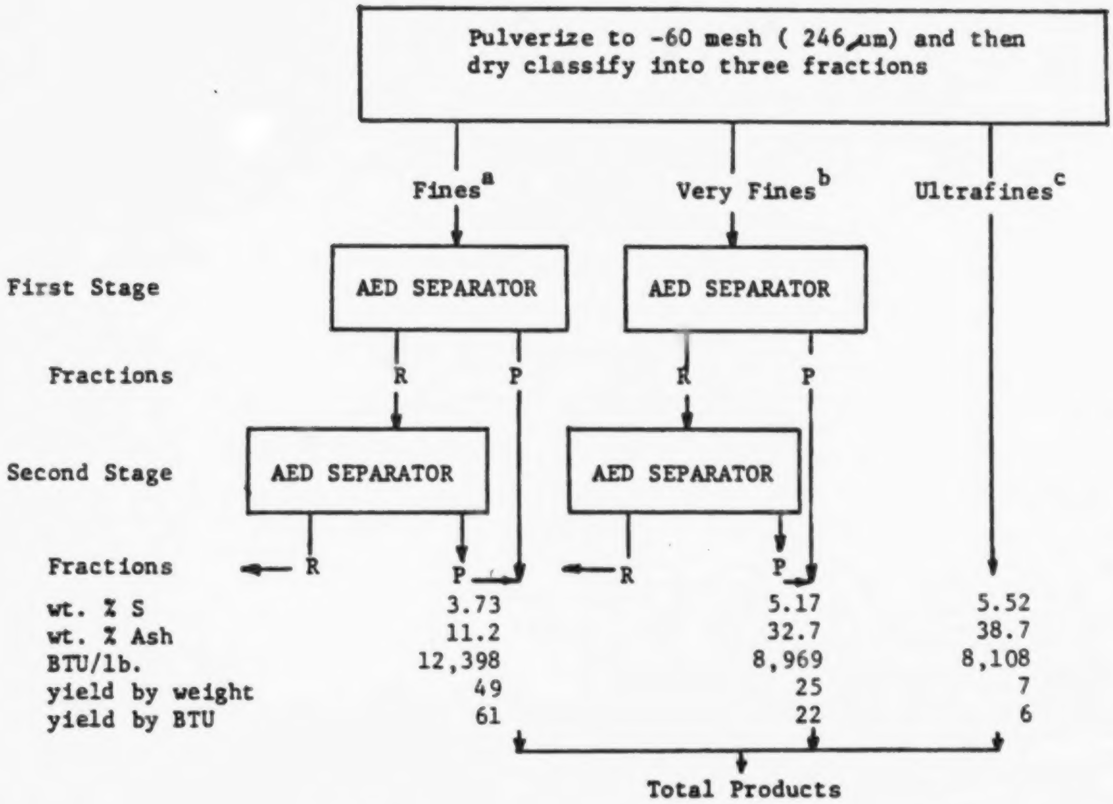
NOTE: R = Rejects
P = Products

TABLE B-27

AED SYSTEM RESULTS, TWO STAGES

COAL: G-6

wt. % S	5.57
wt. % Ash	24.0
BTU/lb	9,940.6


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Total Products

	Fines P	Very Fines P	Ultrafines
wt. % S	3.73	5.17	5.52
wt. % Ash	11.2	32.7	38.7
BTU/lb.	12,398	8,969	8,108
yield by weight	49	25	7
yield by BTU	61	22	6

Total Products

wt. % S	4.33
wt. % Ash	20.2
BTU/lb.	10,967
yield by weight	80
yield by BTU	89

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

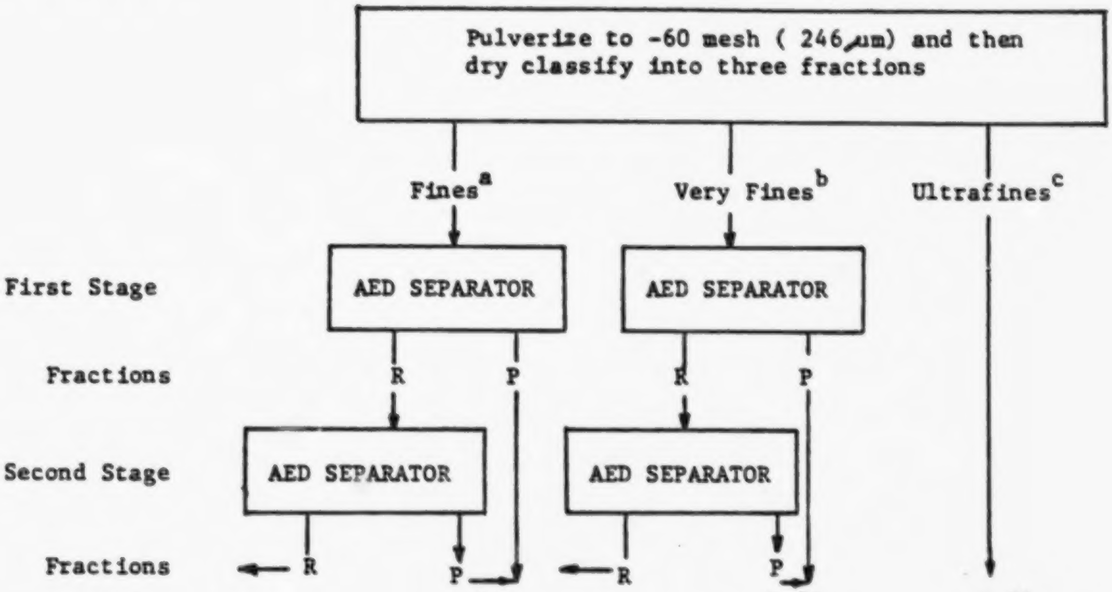
NOTE: R = Rejects
P = Products

TABLE B-28

AED SYSTEM RESULTS, TWO STAGES

COAL: S-1

wt. % S	2.44
wt. % Ash	34.4
BTU/lb	9,624


Pulverize to -60 mesh (246 µm) and then dry classify into three fractions
Fines[a]
Very Fines[b]
Ultrafines[c]
First Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P
Second Stage
AED SEPARATOR
AED SEPARATOR
Fractions
R
P
R
P

	Fines P	Very Fines P	Ultrafines
wt. % S	1.14	1.82	2.64
wt. % Ash	15.8	35.3	40.0
BTU/lb.	12,960	9,308	8,579
yield by weight	44	18	10
yield by BTU	59	17	9

	Total Products
wt. % S	1.53
wt. % Ash	24.2
BTU/lb.	11,413
yield by weight	72
yield by BTU	86

a - Fines are 60 x 270 mesh (246 x 53 µm)

b - Very Fines are 270 mesh x 20 µm (53 x 20 µm)

c - Ultrafines are - 20 µm

NOTE: R = Rejects
P = Products

APPENDIX C

ECONOMIC ANALYSES OF SELECTED PCC PLANTS

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C-9	Summary of Capital Costs, Plant R-6	C-21
C-10	Annualized Costs, Plant R-6	C-22
C-11	Summary of Capital Costs, Plant R-8	C-25
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DESIGN AND COST ESTIMATE BASES

Design Basis

The coal cleaning plant was considered to be composed of 3 sections:

- Raw Coal Storage and Handling.
- Preparation Plant.
- Clean Coal and Refuse Handling.

The basic flow diagram for the raw coal storage and handling section of PCC plants is shown in Figure C-1. Any modifications on this design are stated in the plant process description.

Cost Estimate Basis

Capital Costs -

Total capital cost of a coal preparation plant consists of fixed capital investment, working capital, and land. The fixed capital investment is the capital needed to purchase and install the facilities necessary for the operation of the preparation plant. It consists of direct and indirect costs and contingencies. The direct costs are composed of the installed cost for the raw coal storage and handling facilities, preparation plant and miscellaneous facilities and equipment. The installed direct cost of the preparation plant was estimated to be 2.35 times the cost of the shipped equipment (FOB cost and freight).

Indirect installation costs are necessary for the operation of the overall facility, but they cannot be attributed to any specific equipment. Indirect installation costs include such items as engineering, construction and field expenses, and construction fees. Each of these cost items are estimated to be 10 percent of the total direct costs.

Contingency costs are the excess account set up to deal with uncertainties in the cost estimate, including unforeseen escalation in cost items, malfunctions, equipment design alterations, overlooked costs, and other similar sources. In this study, start-up and performance tests are also considered part of contingencies. Contingencies are estimated to be 25 percent of the sum of direct and indirect costs.

The total turnkey cost is the capital required to purchase and install the equipment for the operation of a preparation plant. The turnkey cost is the sum of total direct costs, indirect installation costs, and contingencies.

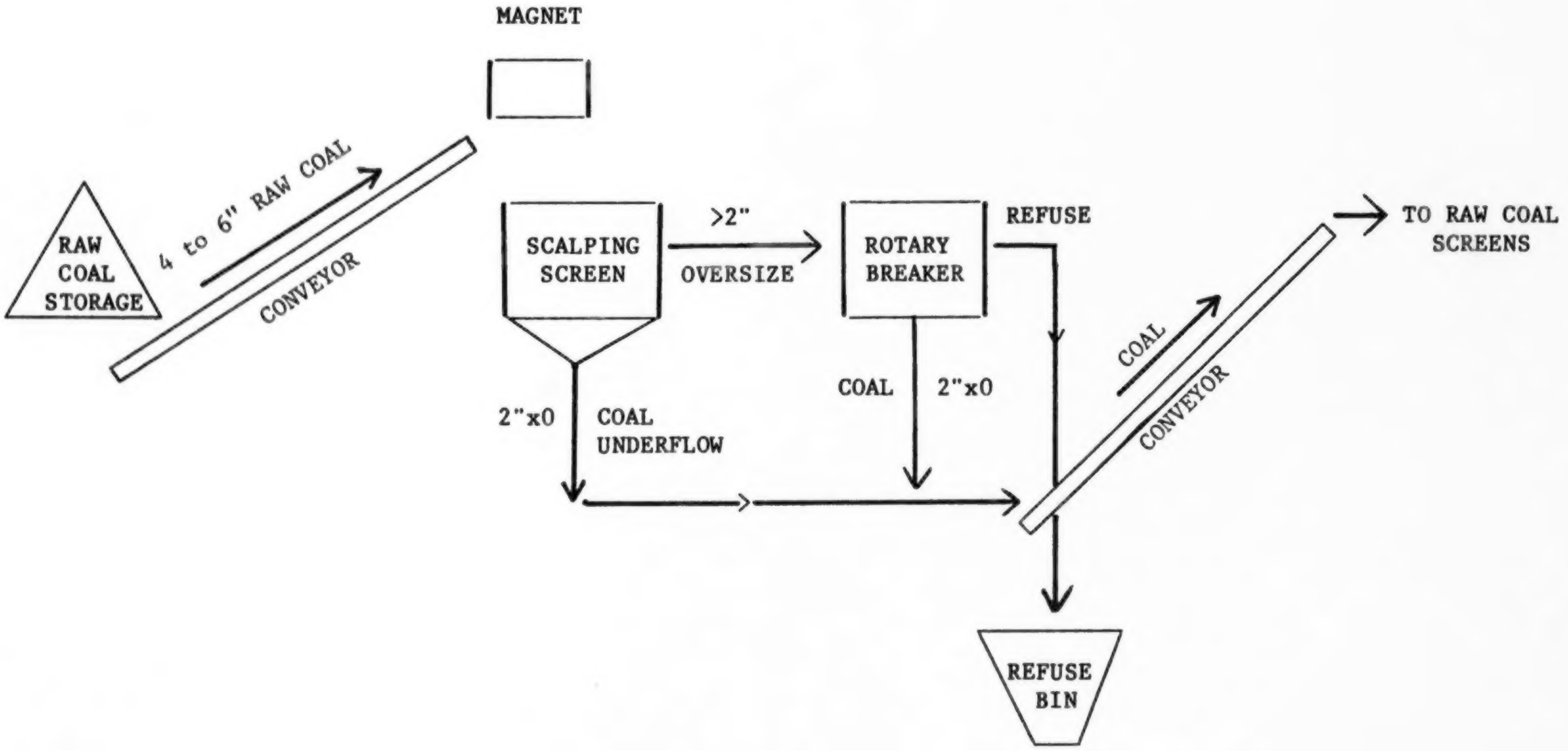

MAGNET
RAW COAL STORAGE
4 to 6" RAW COAL
CONVEYOR
SCALPING SCREEN
>2"
OVERSIZE
ROTARY BREAKER
REFUSE
TO RAW COAL SCREENS
2"x0
COAL UNDERFLOW
COAL
2"x0
COAL
CONVEYOR
REFUSE BIN

Figure C-1. Raw coal storage and handling.

Land, although normally considered to be part of direct costs, was considered separately in this study since it is neither depreciated over the life of the project nor included in total turnkey costs.

Working capital includes costs for raw material stocks and a fund to cover operation and maintenance of the preparation plant for a short period of time. The working capital is estimated to be 25 percent of direct operating costs.

Annualized Costs -

Annualized costs consist of direct costs, overhead costs, and capital charges. Direct and overhead costs are those costs which are attributable to the operation of the plant, whereas capital charges refer to items associated with owning the equipment.

Direct costs include operating and maintenance labor, supervision, maintenance materials and replacement parts, electricity, water, waste disposal and chemicals. Direct labor costs are estimated based on two shifts of operations totalling 13.3 hours per day and a third shift for maintenance. The plants are assumed to operate 250 days per year. Table C-1 presents the estimated manpower requirements.

Maintenance materials and replacement parts are assumed to be 7 percent of the total turnkey cost. The unit cost of waste disposal is assumed to vary with the annual quantity of solid waste. The solid waste disposal cost is estimated from the relationship:

$$Y = (0.0195)\ (10^{-10})\ x^{2} - (0.456 \times 10^{-5})x+3.75$$

where,

Y is the solid disposal cost, \$/ton. (Mid 1978 dollars).
X is the annual quantity of solid waste, tons/year.

This relationship was derived using the information provided in the literature(1) and performing a cost sensitivity analysis for various quantities of solid wastes. The solid disposal cost includes the cost of site development, labor, equipment, operating expenses, and other miscellaneous items.

Electricity, water, and chemical [magnetite, flocculant, and methylisobutyl carbinol (MIBC), and fuel oil] costs are based on the annual usage of the plant and the unit cost. Table C-2 lists the unit prices for various direct cost items employed in this study.

The overhead costs represent a business expense that is not charged directly to a particular part of the process but allocated to it. Overhead costs are broken down into payroll and plant overhead. Payroll overhead is assumed to be 40 percent of direct labor, supervision, and maintenance

TABLE C-1. PLANT MANPOWER REQUIREMENT

1. Supervision:	
- Supervisor	1
- General Foreman	1
	2
2. Operating Shift (2 shifts/day)	
- Foreman	1
- Plant Operators	2
- Dozer Operator	1
- Utility Man	1
	5
3. Maintenance Shift	
- Foreman	1
- Mechanics	5
- Electrician	1
- Utility Man	1
	8

TABLE C-2. UNIT PRICES FOR VARIOUS ITEMS OF ANNUALIZED COSTS

Direct Labor	$23,700/man year
Supervision	$30,400/man year
Maintenance Labor	$23,700/man year
Electricity	25.8 mils/kwh
Water	$0.15/10 gal
Magnetite	$65.0/ton
MIBC	$0.69/ℓ
Fuel	$0.30/gal

labor. Plant overhead is assumed to be 30 percent of direct, indirect and maintenance labor, maintenance parts, and chemicals.

The capital charges are those costs related to the capital investment. Capital charges consist of the capital recovery factor, G&A, taxes, and insurance, and interest on working capital. These costs were determined in the following manner:

- Capital Recovery Factor = 0.1175 x (total turnkey costs).
- G&A, Taxes & Insurance = 0.04 x (total turnkey costs).
- Interest on Working Capital = 0.10 x (working capital)
  = 0.025 x (total direct costs).

The annualized costs do not include the cost of the feed coal to the PCC plant. The cleaning costs, expressed in terms of \$/ton product and $\$/10^6$ Btu product, do neither include the cost of coal nor the profit made by the PCC plant operator.

PHYSICAL COAL CLEANING PLANT DESIGNS AND COSTS

This section contains the process flow descriptions, process flow diagrams, and capital and annual operating costs for each of the six designs considered in this study.

Plant B-1

Process Description (Figure C-2)--

The feed coal to the plant, after being handled as shown in Figure C-1, is sized at 0.38 cm (3/8 in.). The oversize coal is deslimed and then cleaned in a dense-medium vessel. The product and refuse streams from the dense-medium vessel are dewatered by their respective dewatering screens. The 0.38 cm top size coal from the sizing and desliming screens is classified at 28 mesh by classifying cyclones. The coarser fraction is cleaned in concentrating tables. The product and refuse streams from the table, after being dewatered, join the plant clean coal and refuse, respectively.

The overflow from the classifying cyclones is first cleaned by hydrocyclones and the underflow is further cleaned by concentrating tables. The hydrocyclone overflow stream is classified by a series of cyclones and screens. The finer fraction from classification is cleaned in froth flotation cells. The clean coal from the cells and the oversize material from the classification circuit are dewatered before joining the plant product.

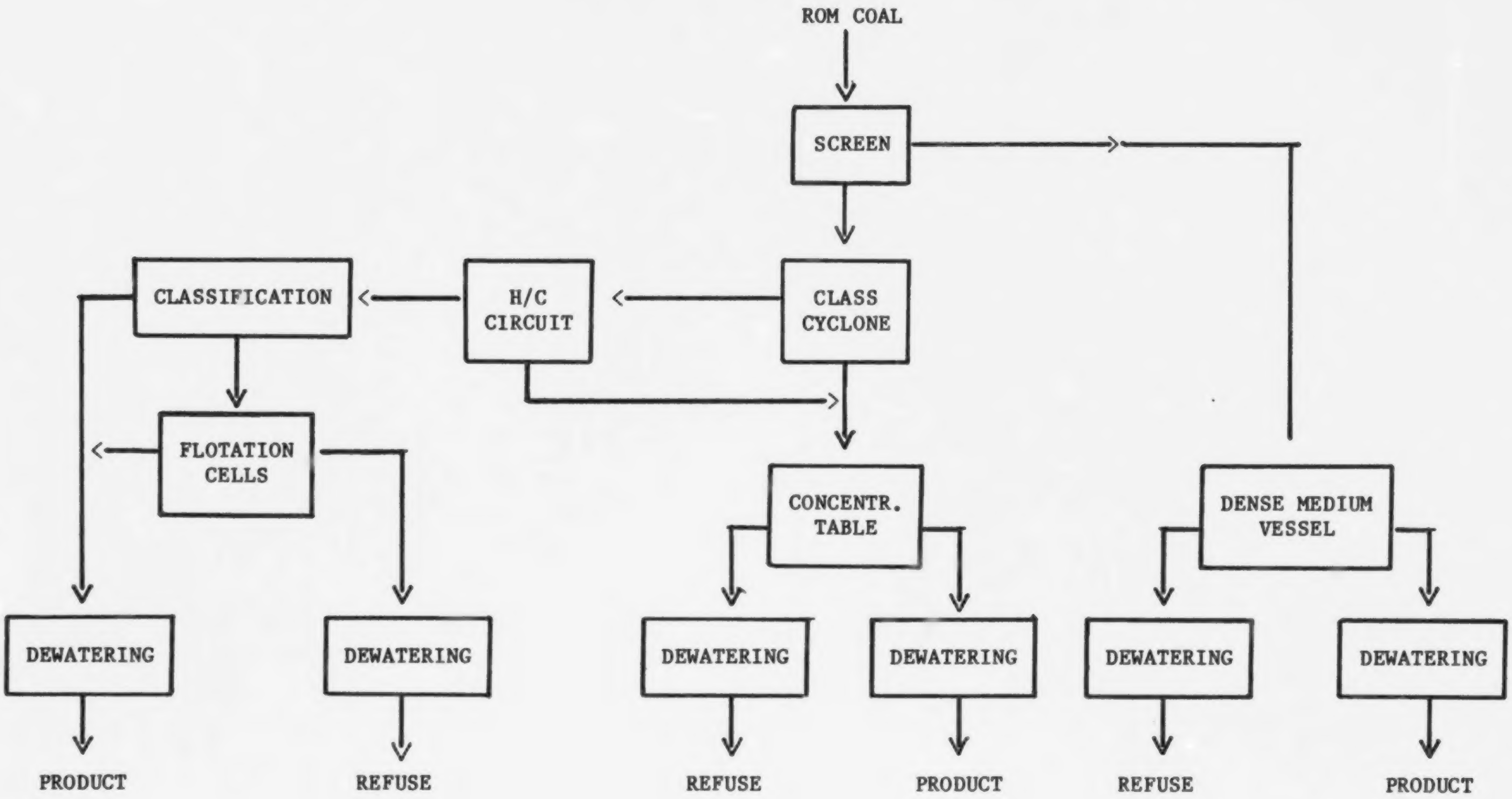

ROM COAL
SCREEN
CLASS CYCLONE
H/C CIRCUIT
CLASSIFICATION
FLOTATION CELLS
CONCENTR. TABLE
DENSE MEDIUM VESSEL
DEWATERING
DEWATERING
DEWATERING
DEWATERING
DEWATERING
DEWATERING
PRODUCT
REFUSE
REFUSE
PRODUCT
REFUSE
PRODUCT

Figure C-2. Process Flow Diagram of Plant B-2.

Costs -

The estimated capital and operating costs for Plant B-1 are shown in Tables C-3 and C-4, respectively.

Plant B-3

Process Description (Figure C-3)

The raw coal handling section of plant B-3 is the same as the one shown in Figure C-1. The ROM coal is first screened at 1.91 cm (0.75 in.). The oversize coal is cleaned in dense-medium vessels. The product and refuse streams from this circuit are dewatered by their respective sieve bends and/or drain-and-rinse screens.

The undersize coal from the sizing screens is deslimed at 28 mesh. The oversize from the desliming screens is cleaned in dense-medium cyclones. The cyclone overflow and underflow streams are dewatered and join the plant clean coal and refuse streams, respectively.

The undersize coal from the desliming screens is cleaned in a hydrocyclone circuit. The product from this circuit joins the plant product.

The clean coal products from the coarse, intermediate, and fine coal circuits are conveyed to the product silo before shipment to the market.

Costs -

The estimated capital and operating costs from plant B-3 are shown in Tables C-5 and C-6, respectively.

Plant R-3

Process Description (Figure C-4)

The feed coal to the plant, after being handled as shown in Figure C-1, is screened at 1.28 cm (0.5 in.). The oversize coal from the sizing screens is cleaned in a jig circuit. The jig product is first dewatered by a combination of sieve bends and dewatering screens, and then crushed before joining the plant clean coal stream. The refuse from the jig is dewatered by a dewatering screen and is collected in the refuse bin. The middlings from the jig circuit are crushed and then recycled to the raw coal screens for sizing. The underflow stream from the sizing screen is cleaned by hydrocyclones. The underflow from the hydrocyclones is dewatered and joins the plant refuse stream. The overflow from the hydrocyclones joins the plant product stream after being dewatered. Fine coal from the dewatering equipment is recovered in a hydrocylone circuit and added to the plant product stream.

TABLE C-3. SUMMARY OF CAPITAL COSTS

PLANT B-1

(Mid 1978 $)

Raw Coal Storage and Handling		1,127,000	
Preparation Plant Equipment Cost	1,454,600		
Total Cost of Preparation Plant (2.35 x Prep. Plant Equipment Cost)		3,418,000	
Miscellaneous Facilities and Equipment		1,539,000	
TOTAL DIRECT COSTS			6,084,000
INSTALLATION COSTS, INDIRECT			
Engineering (10% of direct costs)		608,000	
Construction & Field Expense (10% of direct costs)		608,000	
Construction Fees (10% of direct costs)		608,000	
TOTAL INDIRECT COSTS			1,824,000
CONTINGENCIES			
(25% of direct & indirect costs) (includes start-up and performance tests)			1,977,000
TOTAL TURNKEY COSTS			9,885,000
LAND			264,000
WORKING CAPITAL			
(25% of direct operating costs)			610,000
TOTAL CAPITAL INVESTMENT			10,759,000

TABLE C-4. ANNUALIZED COSTS

PLANT B-1

(Mid 1978 $)

Direct Labor (10 man-yr x $23,700/man-yr)	237,000	
Supervision (2 man-yr x $30,400/man-yr)	60,800	
Maintenance Labor (8 man-yr x $23,700/man-yr)	189,600	
Maintenance Materials & Replacement Parts (7% of total turnkey costs)	692,000	
Electricity (25.8 mils/kwh x 2,500 kw x 3,325 h/yr)	214,500	
Water ($0.15/$10^3$ gal x 1.7 x 10^6 gal/yr)	2,600	
Waste Disposal ($2.00/ton x 4.79 x 10^5 tons/yr)	957,000	
Chemicals (magn: 970 tons/yr x $65/ton) floc: 2.73 tons/yr x $3,000/ton) MIBC: 1.6 x 10^4 ℓ/yr x $0.69/$\ell$) fuel oil: 9.5 x 10^3 gal/yr x 0.30/gal)	85,000	
TOTAL DIRECT COST		2,438,500
Payroll (40% of direct & indirect & maintenance labor)	195,000	
Plant Overhead (30% of direct, indirect & maintenance labor, & maintenance & chemicals)	379,300	
TOTAL OVERHEAD COST		574,300
Capital Recovery Factor (11.75% of total turnkey costs)	1,161,500	
G&A, Taxes & Insurance (4% of total turnkey cost)	395,400	
Interest on Working Capital (10% of W.C.)	61,000	
TOTAL CAPITAL CHARGES		1,617,900
TOTAL ANNUALIZED COSTS		4,630,700
Cost Per Ton of Moisture Free Product		3.03
Cost Per 10^6 Btu of Moisture Free Product		0.110

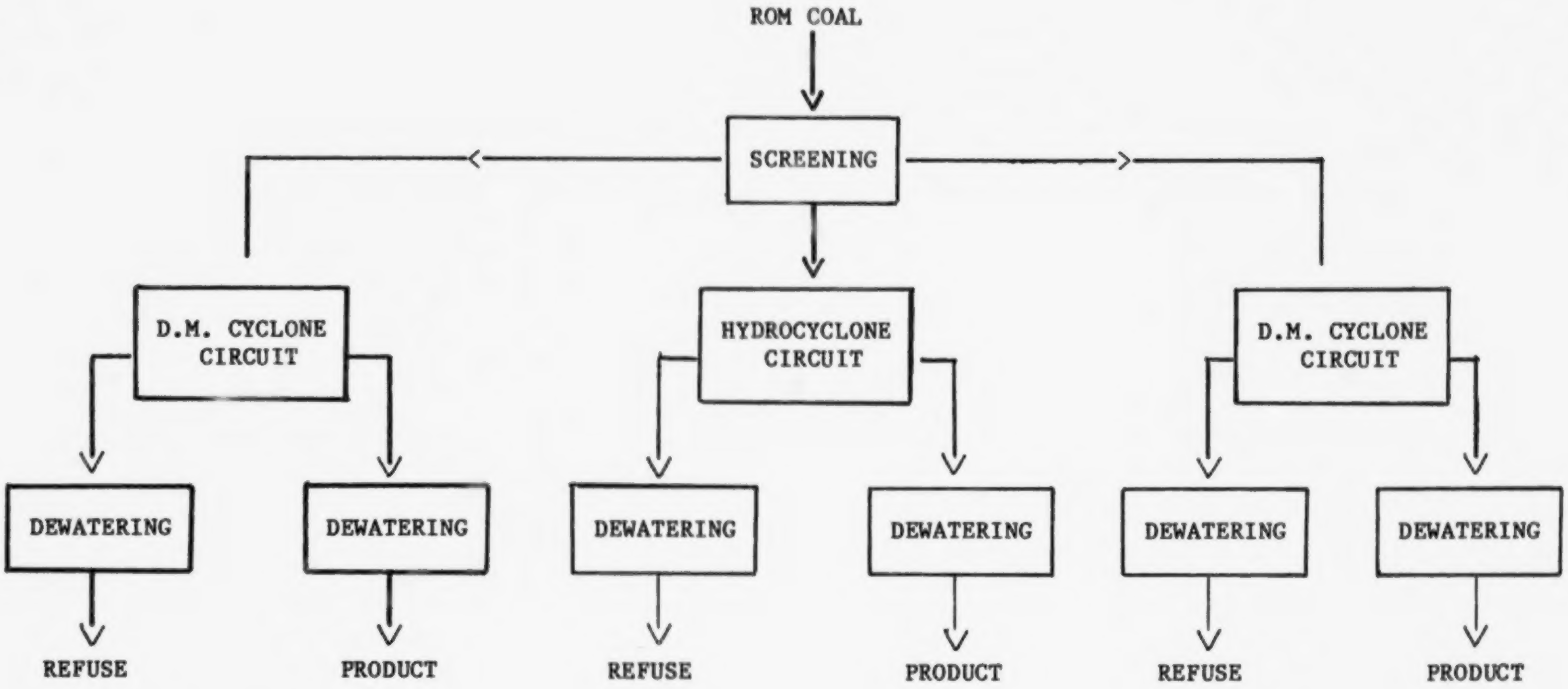

ROM COAL
SCREENING
D.M. CYCLONE CIRCUIT
HYDROCYCLONE CIRCUIT
D.M. CYCLONE CIRCUIT
DEWATERING
DEWATERING
DEWATERING
DEWATERING
DEWATERING
DEWATERING
REFUSE
PRODUCT
REFUSE
PRODUCT
REFUSE
PRODUCT

Figure C-3. Process Flow Diagram of Plant B-3.

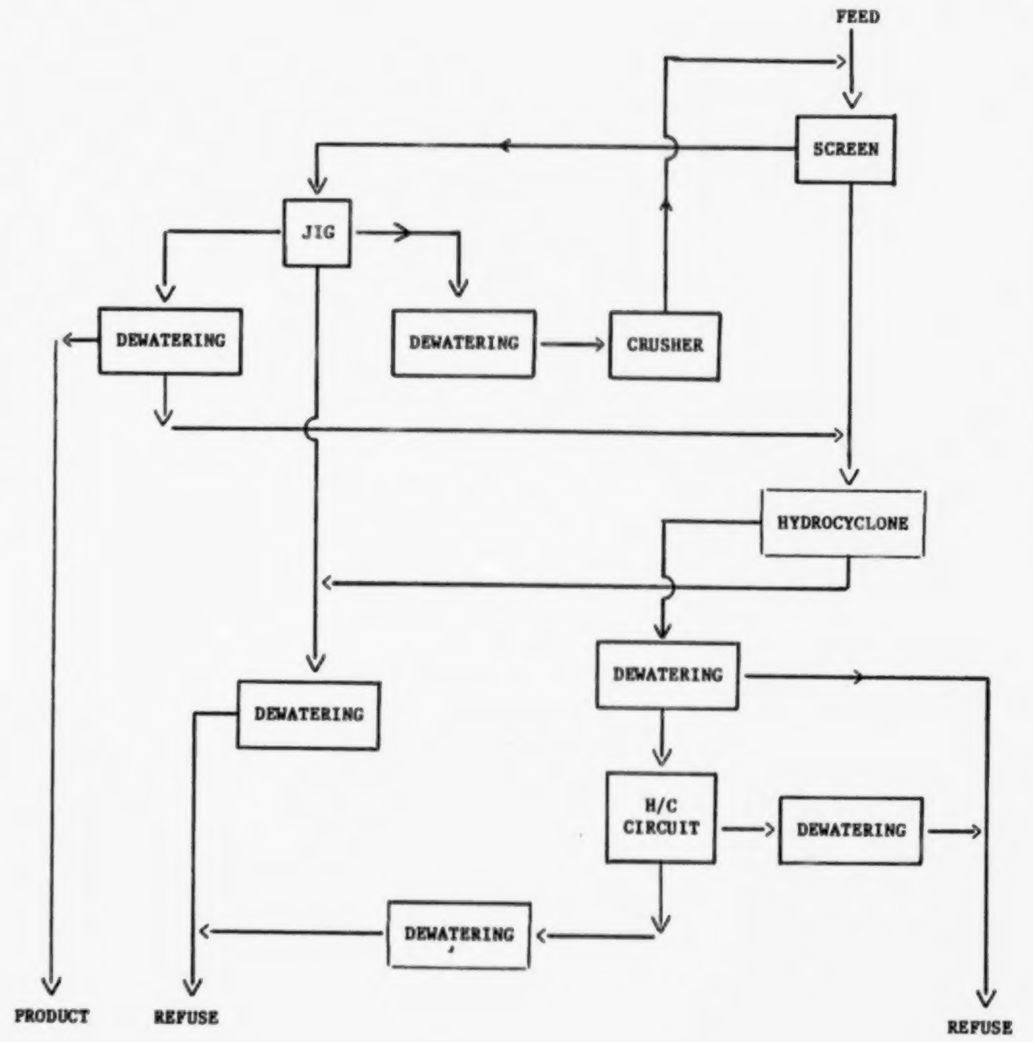

FEED
SCREEN
JIG
DEWATERING
DEWATERING
CRUSHER
HYDROCYCLONE
DEWATERING
DEWATERING
H/C CIRCUIT
DEWATERING
DEWATERING
PRODUCT
REFUSE
REFUSE

Figure C-4. Process Flow Diagram of Plant R-3.

TABLE C-5. SUMMARY OF CAPITAL COSTS

PLANT B-3

(Mid 1978 $)

Raw Coal Storage and Handling		1,127,000	
Preparation Plant Equipment Cost	1,592,100		
Total Cost of Preparation Plant (2.35 x Prep. Plant Equipment Cost)		3,741,000	
Miscellaneous Facilities and Equipment		2,559,000	
TOTAL DIRECT COSTS			7,467,000
INSTALLATION COSTS, INDIRECT			
Engineering (10% of direct costs)		747,000	
Construction & Field Expense (10% of direct costs)		747,000	
Construction Fees (10% of direct costs)		747,000	
TOTAL INDIRECT COSTS			2,241,000
CONTINGENCIES			
(25% of direct & indirect costs) (includes start-up and performance tests)			2,427,000
TOTAL TURNKEY COSTS			12,135,000
LAND			264,000
WORKING CAPITAL			
(25% of direct operating costs)			676,000
TOTAL CAPITAL INVESTMENT			13,075,000

TABLE C-6. ANNUALIZED COSTS

PLANT B-3

(Mid 1978 $)

Direct Labor (10 man-yr x $23,700/man-yr)	237,000	
Supervision (2 man-yr x $30,400/man-yr)	60,800	
Maintenance Labor (8 man-yr x $23,700/man-yr)	189,600	
Maintenance Materials & Replacement Parts (7% of total turnkey costs)	849,500	
Electricity (25.8 mils/kwh x 3,769 kw x 3,325 h/yr)	323,200	
Water ($0.15/10^3 gal x 2.4 x 10^6 gal/yr)	3,600	
Waste Disposal ($2.00/ton x 4.82 x 10^5 tons/yr)	964,000	
Chemicals (magn: 918 tons/yr x $65/ton) floc: 6.00 tons/yr x $3,000/ton)	77,700	
TOTAL DIRECT COST		2,438,500
Payroll (40% of direct & indirect & maintenance labor)	195,000	
Plant Overhead (30% of direct, indirect & maintenance labor, & maintenance & chemicals)	424,400	
TOTAL OVERHEAD COST		619,400
Capital Recovery Factor (11.75% of total turnkey costs)	1,425,900	
G&A, Taxes & Insurance (4% of total turnkey cost)	485,400	
Interest on Working Capital (10% of W.C.)	67,600	
TOTAL CAPITAL CHARGES		1,978,900
TOTAL ANNUALIZED COSTS		5,303,700
Cost Per Ton of Moisture Free Product		3.47
Cost Per 10^6 Btu of Moisture Free Product		0.137

Costs -

The estimated capital and operating costs for plant R-3 are shown in Tables C-7 and C-8, respectively.

Plant R-6

Process Description (Figure C-5)--

The feed coal, after being handled as shown in Figure C-1, is conveyed to the jig. The product from the jig is dewatered by a series of sieve bends and two-stage dewatering screens. The intermediate oversize fraction from the dewatering screen is further dewatered by centrifuges. This dewatered coal stream joins the coarse size fraction from the two-stage screens.

The fine coal from the two-stage dewatering screen and other dewatering equipment is cleaned in a flotation circuit. The flotation product is cleaned in a filter before joining the plant product.

The middlings from the jig are crushed, are recycled to the jig, and the refuse from the jig is dewatered by a dewatering screen. The screen oversize is conveyed to the refuse bin. The screen undersize and the refuse stream from the flotation cells are thickened and then filtered before disposal.

Costs -

The estimated capital and operating costs for plant R-6 are shown in Tables C-9 and C-10, respectively.

Plant R-8

Process Description (Figure C-6)--

In this plant, the raw coal is stored in silos before being introduced to the process by belt conveyors. The feed coal to the process is first screened at 0.38 cm (3/8 in.). The oversize coal from the sizing screens is cleaned in a dense-medium vessel. The clean coal and refuse streams from the dense-medium vessel are dewatered by their respective sieve bends and dewatering screens.

The undersize coal from the sizing screens is deslimed at 28 mesh. The 0.38 cm x 28 mesh size fraction from the desliming screen is cleaned in dense-medium cyclones. The clean and the refuse coal from the dense-medium cyclones are then dewatered in their respective dewatering equipment.

The desliming screen underflow is first cleaned in a hydrocylone circuit. The hydrocyclone overflow is further cleaned in froth flotation cells. The clean coal stream from the froth flotation cells joins the product from the other circuits after being dewatered.

TABLE C-7. SUMMARY OF CAPITAL COSTS

PLANT R-3

(Mid 1978 $)

Raw Coal Storage and Handling		1,127,000	
Preparation Plant Equipment Cost	1,044,600		
Total Cost of Preparation Plant (2.35 x Prep. Plant Equipment Cost)		2,455,000	
Miscellaneous Facilities and Equipment		1,564,000	
TOTAL DIRECT COSTS			5,146,000
INSTALLATION COSTS, INDIRECT			
Engineering (10% of direct costs)		515,000	
Construction & Field Expense (10% of direct costs)		515,000	
Construction Fees (10% of direct costs)		515,000	
TOTAL INDIRECT COSTS			1,545,000
CONTINGENCIES			
(25% of direct & indirect costs) (includes start-up and performance tests)			1,673,000
TOTAL TURNKEY COSTS			8,364,000
LAND			264,000
WORKING CAPITAL			
(25% of direct operating costs)			619,000
TOTAL CAPITAL INVESTMENT			9,247,000

TABLE C-8. ANNUALIZED COSTS

PLANT R-3

(Mid 1978 $)

Direct Labor (10 man-yr x $23,700/man-yr)	237,000	
Supervision (2 man-yr x $30,400/man-yr)	60,800	
Maintenance Labor (8 man-yr x $23,700/man-yr)	189,600	
Maintenance Materials & Replacement Parts (7% of total turnkey costs)	585,500	
Electricity (25.8 mils/kwh x 2,730 kw x 3,325 h/yr)	234,200	
Water ($0.15/$10^3$ gal x 26.4 x 10^6 gal/yr)	4,000	
Waste Disposal ($1.30/ton x 8.56 x 10^5 tons/yr)	1,113,900	
Chemicals		
floc: 17.4 tons/yr x $3,000/ton)	52,400	
TOTAL DIRECT COST		2,477,400
Payroll (40% of direct & indirect & maintenance labor)	195,000	
Plant Overhead (30% of direct, indirect & maintenance labor, & maintenance & chemicals)	337,600	
TOTAL OVERHEAD COST		532,600
Capital Recovery Factor (11.75% of total turnkey costs)	982,800	
G&A, Taxes & Insurance (4% of total turnkey cost)	334,600	
Interest on Working Capital (10% of W.C.)	61,900	
TOTAL CAPITAL CHARGES		1,379,300
TOTAL ANNUALIZED COSTS		4,389,300
Cost Per Ton of Moisture Free Product		3.58
Cost Per 10^6 Btu of Moisture Free Product		0.137

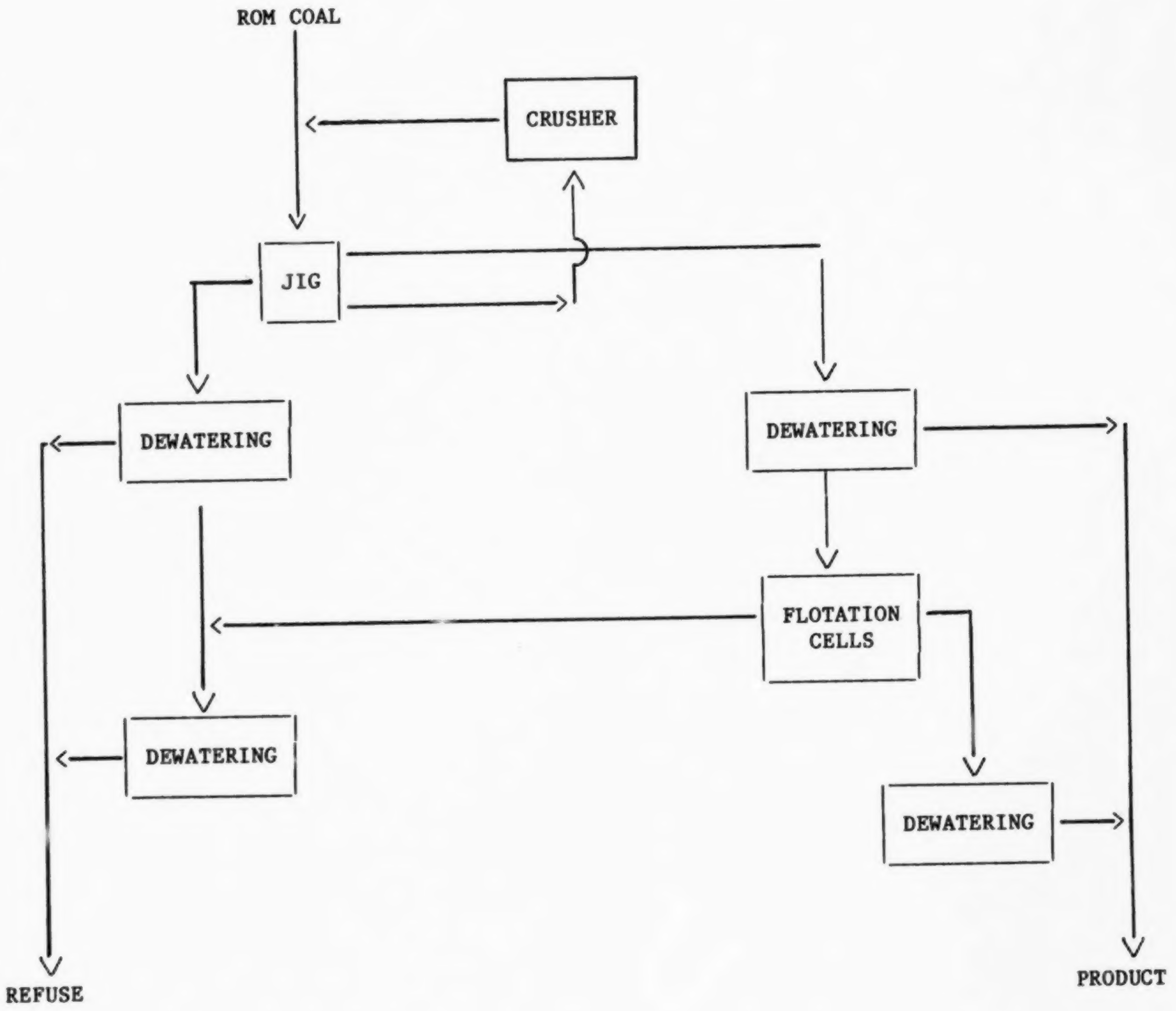

ROM COAL
CRUSHER
JIG
DEWATERING
DEWATERING
FLOTATION CELLS
DEWATERING
DEWATERING
REFUSE
PRODUCT

Figure C-5. Process Flow Diagram of Plant R-6.

TABLE C-9. SUMMARY OF CAPITAL COSTS

PLANT R-6

(Mid 1978 $)

Raw Coal Storage and Handling		1,127,000	
Preparation Plant Equipment Cost	985,200		
Total Cost of Preparation Plant (2.35 x Prep. Plant Equipment Cost)		2,315,000	
Miscellaneous Facilities and Equipment		1,804,000	
TOTAL DIRECT COSTS			5,346,000
INSTALLATION COSTS, INDIRECT			
Engineering (10% of direct costs)		535,000	
Construction & Field Expense (10% of direct costs)		535,000	
Construction Fees (10% of direct costs)		535,000	
TOTAL INDIRECT COSTS			1,605,000
CONTINGENCIES			
(25% of direct & indirect costs) (includes start-up and performance tests)			1,738,000
TOTAL TURNKEY COSTS			8,689,000
LAND			264,000
WORKING CAPITAL			
(25% of direct operating costs)			585,400
TOTAL CAPITAL INVESTMENT			9,538,400

TABLE C-10. ANNUALIZED COSTS

PLANT R-6

(Mid 1978 $)

Direct Labor (10 man-yr x $23,700/man-yr)	237,000	
Supervision (2 man-yr x $30,400/man-yr)	60,800	
Maintenance Labor (8 man-yr x $23,700/man-yr)	189,600	
Maintenance Materials & Replacement Parts (7% of total turnkey costs)	608,200	
Electricity (25.8 mils/kwh x 2,287 kw x 3,325 h/yr)	163,200	
Water ($\$0.15/10^3$ gal x 1.93 x 10^6 gal/yr)	2,900	
Waste Disposal ($\$1.75$/ton x 5.93 x 10^5 tons/yr)	1,039,500	
Chemicals (floc: 9.00 tons/yr x $\$3,000$/ton) MIBC: 1.6 x 10^4 ℓ/yr x $\$0.69$/ℓ) fuel oil: 9.5 x 10^3 gal/yr x 0.30/gal)	40,700	
TOTAL DIRECT COST		2,341,700
Payroll (40% of direct & indirect & maintenance labor)	195,000	
Plant Overhead (30% of direct, indirect & maintenance labor, & maintenance & chemicals)	340,900	
TOTAL OVERHEAD COST		535,900
Capital Recovery Factor (11.75% of total turnkey costs)	1,021,000	
G&A, Taxes & Insurance (4% of total turnkey cost)	347,600	
Interest on Working Capital (10% of W.C.)	58,600	
TOTAL CAPITAL CHARGES		1,427,200
TOTAL ANNUALIZED COSTS		4,304,800
Cost Per Ton of Moisture Free Product		3.00
Cost Per 10^6 Btu of Moisture Free Product		0.117

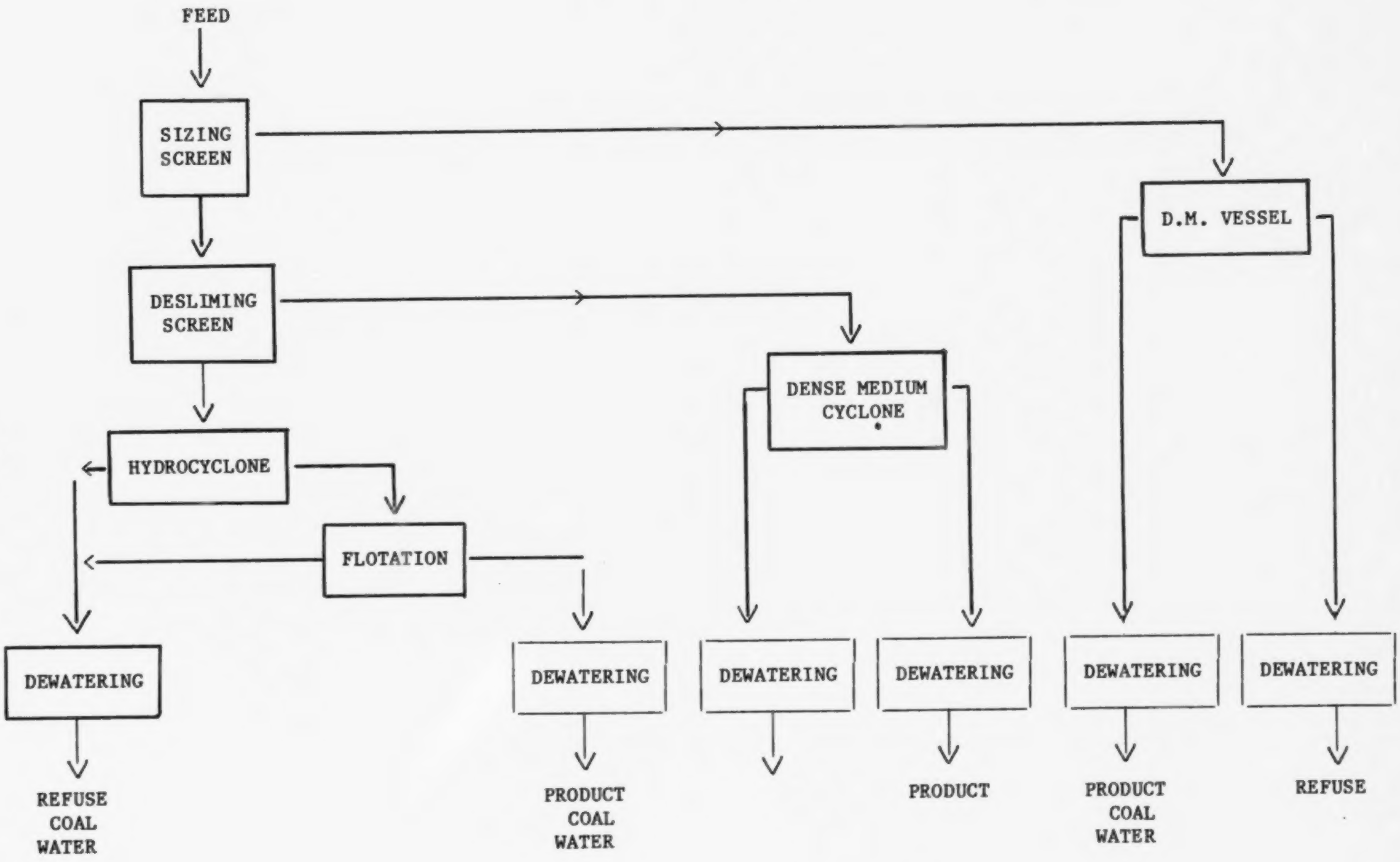

FEED
SIZING SCREEN
DESLIMING SCREEN
HYDROCYCLONE
FLOTATION
DENSE MEDIUM CYCLONE
D.M. VESSEL
DEWATERING
DEWATERING
DEWATERING
DEWATERING
DEWATERING
DEWATERING
REFUSE COAL WATER
PRODUCT COAL WATER
PRODUCT
PRODUCT COAL WATER
REFUSE

Figure C-6. Process Flow Diagram of Plant R-8.

The underflow from the hydrocyclone and the refuse stream from the froth flotation cells are dewatered before being conveyed to the refuse bin.

Costs -

The estimated capital and operating costs for plant R-8 are shown in Tables C-11 and C-12.

Plant S-1

Process Description (Figure C-7)--

The feed coal to the plant, after being handled as shown in Figure C-1 is sized at 0.8 cm (5/16 in.). The oversize coal is first prewetted, and then introduced into a dense-medium vessel. The clean coal and the refuse streams from the vessel are dewatered in their respective sieve bends and drain-and-rinse screens.

The undersize coal from sizing screens is further sized by sieve bends. The oversize is cleaned in concentrating tables and the undersize in froth flotation cells. The clean coal and the refuse streams from these circuits are dewatered by their respective dewatering equipment.

The clean coal from various circuits are conveyed to the clean coal storage pile by belt conveyors.

Costs -

The estimated capital and operating costs for plant S-1 are shown in Tables C-13 and C-14, respectively.

RESULTS

The results of cost analyses of six PCC plants described in this section are summarized in Table C-15. It should be kept in mind that the information provided here is based on a conceptual plant size (600 tph feed flowrate), using the design and cost assumptions given in this section. It should also be remembered that the feed and clean coal characteristics were obtained from analysis of grab samples which may not be representative of the plant feed and product streams.

The turnkey costs for the six PCC plants varied from 8.3 to 12.1 million (mid-1978) dollars, and the annualized costs (excluding the cost of coal) were between 4.6 and 5.3 million dollars. The cleaning cost per ton of clean coal was estimated to be the lowest for plant R-6 ($3.03/ton clean coal). However, plant B-1 was found to have the lowest cleaning costs when these costs are expressed per unit of energy in the clean coal or per amount of sulfur removed (11.0¢/10^6 Btu clean coal, and 6.3¢/lb S removed, respectively).

TABLE C-11. SUMMARY OF CAPITAL COSTS

PLANT R-8

(Mid 1978 $)

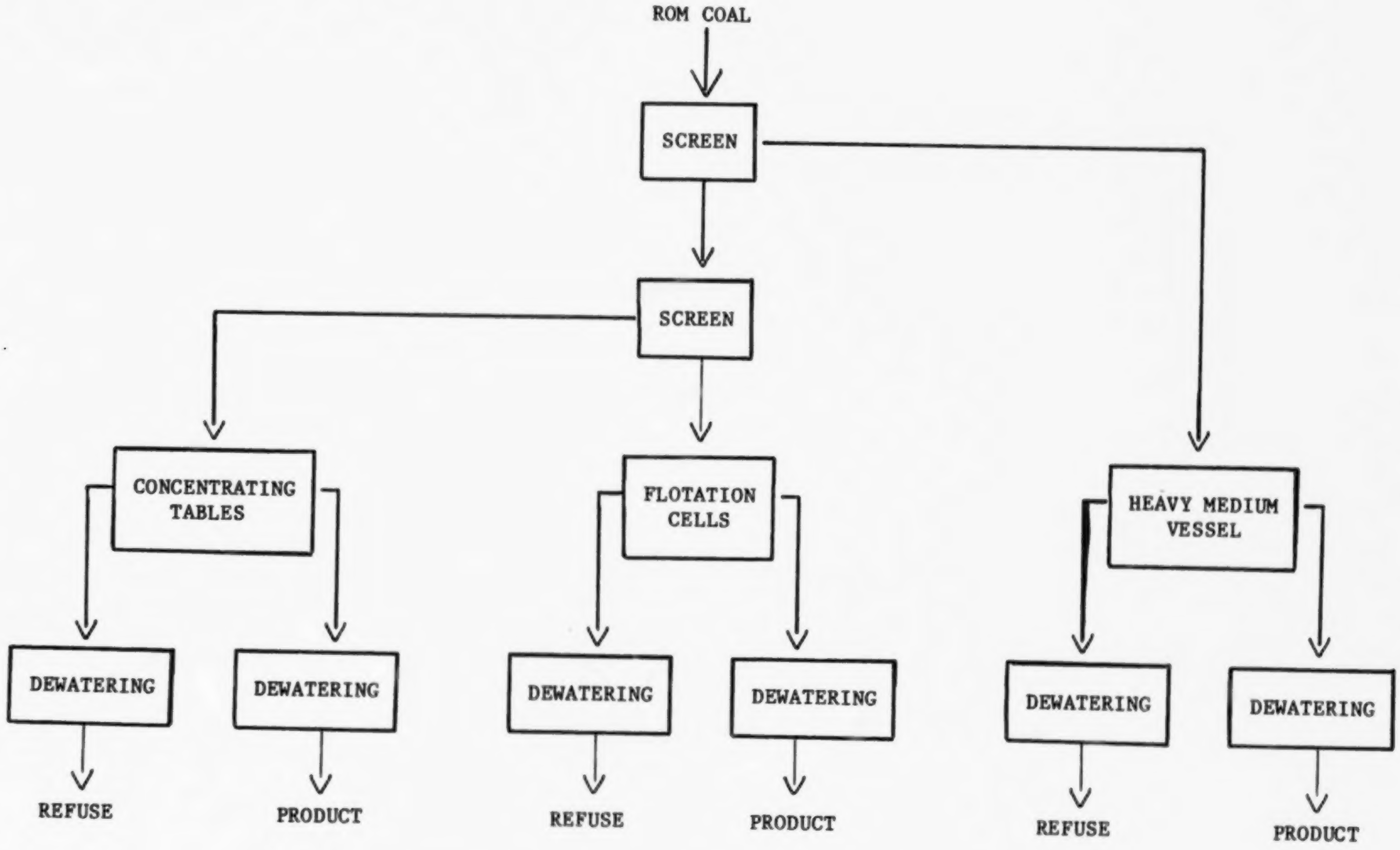
Raw Coal Storage and Handling		1,868,000	
Preparation Plant Equipment Cost	1,639,200		
Total Cost of Preparation Plant (2.35 x Prep. Plant Equipment Cost)		3,851,000	
Miscellaneous Facilities and Equipment		1,419,000	
TOTAL DIRECT COSTS			7,138,000
INSTALLATION COSTS, INDIRECT			
Engineering (10% of direct costs)		714,000	
Construction & Field Expense (10% of direct costs)		714,000	
Construction Fees (10% of direct costs)		714,000	
TOTAL INDIRECT COSTS			2,142,000
CONTINGENCIES			
(25% of direct & indirect costs) (includes start-up and performance tests)			2,320,000
TOTAL TURNKEY COSTS			11,600,000
LAND			264,000
WORKING CAPITAL			
(25% of direct operating costs)			676,000
TOTAL CAPITAL INVESTMENT			12,540,000

TABLE C-12. ANNUALIZED COSTS

PLANT R-8

(Mid 1978 $)

Direct Labor (10 man-yr x $23,700/man-yr)	237,000	
Supervision (2 man-yr x $30,400/man-yr)	60,800	
Maintenance Labor (8 man-yr x $23,700/man-yr)	189,600	
Maintenance Materials & Replacement Parts (7% of total turnkey costs)	812,000	
Electricity (25.8 mils/kwh x 2,483 kw x 3,325 h/yr)	213,000	
Water ($0.15/$10^3$ gal x 24.7 x 10^6 gal/yr)	3,700	
Waste Disposal ($1.20/ton x 9.2 x 10^5 tons/yr)	1,105,500	
Chemicals (magn: 1,140 tons/yr x $65/ton) (floc: .50 tons/yr x $3,000/ton) (MIBC: 8.0 x 10^4 ℓ/yr x $0.69/ℓ) (fuel oil: 4.7 x 10^3 gal/yr x 0.30/gal)	82,500	
TOTAL DIRECT COST		2,703,600
Payroll (40% of direct & indirect & maintenance labor)	195,000	
Plant Overhead (30% of direct, indirect & maintenance labor, & maintenance & chemicals)	414,600	
TOTAL OVERHEAD COST		609,600
Capital Recovery Factor (11.75% of total turnkey costs)	1,363,000	
G&A, Taxes & Insurance (4% of total turnkey cost)	464,000	
Interest on Working Capital (10% of W.C.)	67,600	
TOTAL CAPITAL CHARGES		1,894,600
TOTAL ANNUALIZED COSTS		5,207,800
Cost Per Ton of Moisture Free Product		4.61
Cost Per 10^6 Btu of Moisture Free Product		0.165


ROM COAL
SCREEN
SCREEN
CONCENTRATING TABLES
FLOTATION CELLS
HEAVY MEDIUM VESSEL
DEWATERING
DEWATERING
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DEWATERING
DEWATERING
REFUSE
PRODUCT
REFUSE
PRODUCT
REFUSE
PRODUCT

Figure C-7. Process Flow Diagram of Plant S-1.

TABLE C-13. SUMMARY OF CAPITAL COSTS

PLANT S-1

(Mid 1978 $)

Raw Coal Storage and Handling		1,127,000	
Preparation Plant Equipment Cost	1,755,000		
Total Cost of Preparation Plant (2.35 x Prep. Plant Equipment Cost)		4,124,000	
Miscellaneous Facilities and Equipment		1,711,000	
TOTAL DIRECT COSTS			6,962,000
INSTALLATION COSTS, INDIRECT			
Engineering (10% of direct costs)		696,000	
Construction & Field Expense (10% of direct costs)		696,000	
Construction Fees (10% of direct costs)		696,000	
TOTAL INDIRECT COSTS			2,088,000
CONTINGENCIES			
(25% of direct & indirect costs) (includes start-up and performance tests)			2,263,000
TOTAL TURNKEY COSTS			11,313,000
LAND			264,000
WORKING CAPITAL			
(25% of direct operating costs)			642,000
TOTAL CAPITAL INVESTMENT			12,219,000

TABLE C-14. ANNUALIZED COSTS

PLANT S-1

(Mid 1978 $)

Direct Labor (10 man-yr x \$23,700/man-yr)	237,000	
Supervision (2 man-yr x \$30,400/man-yr)	60,800	
Maintenance Labor (8 man-yr x \$23,700/man-yr)	189,600	
Maintenance Materials & Replacement Parts (7% of total turnkey costs)	791,900	
Electricity (25.8 mils/kwh x 2,430 kw x 3,325 h/yr)	208,500	
Water (\$0.15/10^3 gal x 33.5 x 10^6 gal/yr)	5,000	
Waste Disposal (\$1.20/ton x 9.08 x 10^5 tons/yr)	1,135,000	
Chemicals (magn: 15,960 tons/yr x \$65/ton) (floc: 9,490 tons/yr x \$3,000/ton)	47,100	
TOTAL DIRECT COST		2,568,500
Payroll (40% of direct & indirect & maintenance labor)	195,000	
Plant Overhead (30% of direct, indirect & maintenance labor, & maintenance & chemicals)	397,900	
TOTAL OVERHEAD COST		592,900
Capital Recovery Factor (11.75% of total turnkey costs)	1,329,300	
G&A, Taxes & Insurance (4% of total turnkey cost)	452,500	
Interest on Working Capital (10% of W.C.)	64,200	
TOTAL CAPITAL CHARGES		1,846,000
TOTAL ANNUALIZED COSTS		5,113,400
Cost Per Ton of Moisture Free Product		4.28
Cost Per 10^6 Btu of Moisture Free Product		0.153

TABLE C-15. COST OF CLEANING COAL AT SIX PCC PLANTS

		PLANT					
		B-1	B-2	R-3	R-6	R-8	S-1
Total Turnkey Cost* ($)		9,885,000	12,135,000	8,364,000	8,689,000	11,600,000	11,313,000
Total Annualized Costs* ($)		4,631,000	5,303,700	4,304,000	5,207,800	5,207,800	5,113,400
Weight Recovery** (%)		80	80	64	75	60	61
Cleaning Cost*	$/ton clean coal$^+$	3.03	3.47	3.58	3.00	4.61	4.28
	¢/10^6 Btu clean coal	11.0	13.7	13.7	11.7	16.5	15.3
	¢/1b S removed	6.3	11.6	7.8	10.4	116.9	7.5

* Mid 1978 dollars. Does not include the cost of coal and the profit.
** As received basis, estimated by plant operator.
+ Moisture free basis.
. Excludes cost of coal.

For plant R-8, the cleaning costs, in terms of ¢/lb S removed, is much higher than for the other plants since this process removes ash rather than sulfur from coal.

REFERENCE

1. Brown, R.E., et al. Economic Evaluation of Coal Refuse Disposal Systems. Paper presented at the Third Symposium on Coal Preparation. NCA/BCR Coal Conference and Expo IV. October 18-20, 1977. Louisville, Kentucky.

APPENDIX D

ECONOMIC ANALYSES OF PROCESS CONCEPTS USING THE AED COAL CLEANING PROCESS

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INTRODUCTION

These conceptual designs and economic analyses are based upon the conceptual design and economic analysis prepared jointly by Stone & Webster Engineering Corporation and Advanced Energy Dynamics, Inc. (AED), in June 1980. The earlier Stone & Webster/AED design presented its economic information along EPRI (Electric Power Research Institute) guidelines. The present study follows process industries methods in accordance with U.S. Environmental Protection Agency guidelines as outlined in EPA-600/a-79-018a by Vincent W. Uhl.

The present study provides an estimate of the capital investment cost and power consumption required by two applications of the AED system. These are:

(a) to install and operate a 125 ton per hour coal cleaning system developed by AED at a typical existing power plant and

(b) to install and operate a 125 ton per hour coal cleaning system at a coal mine.

The AED Advanced Coal Cleaning System uses a novel combination of continuous flow "silent discharge" ionization and low-power electrostatic separation to desulfurize and to remove ash from bituminous coals. At an existing power plant, the AED System is totally dry and is designed to be installed between the pulverizers and the boilers in electric power generation facilities. At a coal mine, pulverizing is necessary before cleaning. Briquetting after cleaning is required to make shipment possible by conventional carriers such as railroad cars, etc.

The total investment costs were estimated by using direct costs, identified in Section 4, obtained from vendors as well as from AED. Total power consumption was estimated for each application, considering the system operating at 100 percent capacity at power plants and at 6000 hr/year at coal mines.

The Appendix section provides economic analyses which yield life-cycle costs for both (a) electric power plant and (b) coal mine applications of the AED system in terms of (1) dollars per ton and (2) dollars per 10^6 Btu.

BASIS

Installation at an Existing Electric Power Plant

This study was based on a particular sample of float/sink washed Pittsburgh No. 8 seam coal from the Powhatan No. 4 Mine, North American Coal Co. obtained by AED and processed to reduce the sulfur and ash content. The data obtained and used as the basis of this study is as follows:

	Feed		Product
	lb/100 lb coal	lb/10^6 Btu	lb/10^6 Btu
• Sulfur	3.85	3.21	2.14
• Ash	15.00	12.50	10.40

This represents a 33 percent reduction of sulfur and a 16.8 percent reduction of ash on a Btu basis. A Btu recovery of 97 percent was measured and calculated. Energy content, cleaned coal, 12,450 Btu/lb.

This study was performed using the above listed data and the following assumptions:

1. The coal cleaning system would be installed at an existing power plant that has at least one boiler requiring 125 tons per hour coal feed.
2. Coal feed to the boiler is through four, 25 percent capacity pulverizers (31.25 TPH) utilizing a direct feed system. Sixteen (16) burners exist.
3. The boiler is designed to operate with 20 percent excess air.
4. Primary air supplied to the pulverizers is 15 percent of the total combustion air.
5. Primary air leaves the pulverizers at 150-160°F and will be returned to the burners with the cleaned coal at approximately the same temperature.
6. Flue gas to inert, fill, and make-up for the system will be lowered in temperature to 150°F.
7. The coal cleaning system will be housed in a structural steel framed building with insulated metal siding, metal decking, and built-up roof. Building heating, ventilation, and fire protection will be provided.
8. Sufficient area exists adjacent to the powerhouse for installation of the coal cleaning system and building.

Costs of the following items have not been included in this study because each is either highly site specific and/or requires detailed engineering prior to estimating. The items are discussed further in the study.

1. Solid waste handling and disposal from the coal cleaning system.
2. Modifications to existing or additional air pollution control equipment, if required.
3. Method of reducing flue gas temperature to 150°F.

4. Emission monitoring requirements.

Installation at a Coal Mine

The portion of the study was based upon a sample of Hagy coal obtained from the Wellmore mine in Buchanan, VA of United Coal Companies obtained by AED and processed to reduce the sulfur and ash content. The data obtained and used as the basis for this portion of the study are as follows:

	Feed		Product
	lb/100 lb coal	lb/10^6 Btu	lb/10^6 Btu
• Sulfur	2.33	2.10	1.74
• Ash	25.00	22.00	9.1

Energy Content, Cleaned Coal, 13,147 Btu/lb.

This represents a 37 percent reduction of sulfur and a 59 percent reduction of ash on a Btu basis. A Btu recovery of 85 percent was measured and calculated. The study was performed using the above list of data and the following assumptions:

1. The coal cleaning system would be installed at a coal mine.
2. Coal feed to the system passes first through four, 25 percent capacity pulverizers (35.0 TPH) utilizing a direct feed system.
3. The cleaned coal is taken to a briquetter to transform the product coal into briquets suitable for shipment by conventional carriers such as railroad cars, etc.
4. The pulverized coal processing system will be inerted with nitrogen or flue gas, requiring only make-up to compensate for gas leaks in the sealed, inerted system.
5. Portions of the AED Coal Cleaning System that require protection from the elements will be housed in a structural steel framed building with insulated metal siding, metal decking, and buuilt-up roof. Building heating, ventilation, and fire protection will be provided.
6. Sufficient area exists at the coal mine for the installation of all equipment without incurring expense to purchase additional land.

Costs of the following items have not been included in this study because each is either highly site specific and/or requires detailed engineering prior to estimating:

1. Solid waste handling and disposal in the coal cleaning system.
2. Emission monitoring requirements.

DISCUSSION

A mass balance of the coal cleaning system was performed utilizing coal measurement and system data and the assumptions outlined in the above Section 2 (BASIS) of this study. The mass balance is provided as Figure D-1. It should be noted that the degree of sulfur and ash removal and Btu recovery is dependent on the composition and characteristics of the coal feed. Therefore, Figure D-1 is valid only for this particular coal sample.

A conceptual engineering effort was performed to identify equipment, installation and operating costs. This study was not intended to provided a detailed engineering analysis of the system. Should a particular installation be identified, a detailed engineering effort would be required to provide a more accurate estimate.

During the course of this study, certain items have been identified that may significantly alter the system design and costs. In particular, the following items would require further analysis to insure proper operation and/or cost estimate accuracy:

1. System design
2. Material handling
3. Location of installation with respect to powerhouse
4. Preparation of makeup flue gas
5. System controls including load follow capability
6. Solids waste disposal
7. Effects on air pollution control equipment
8. Emission monitoring requirements
9. Permitting

A brief discussion of each item listed above follows:

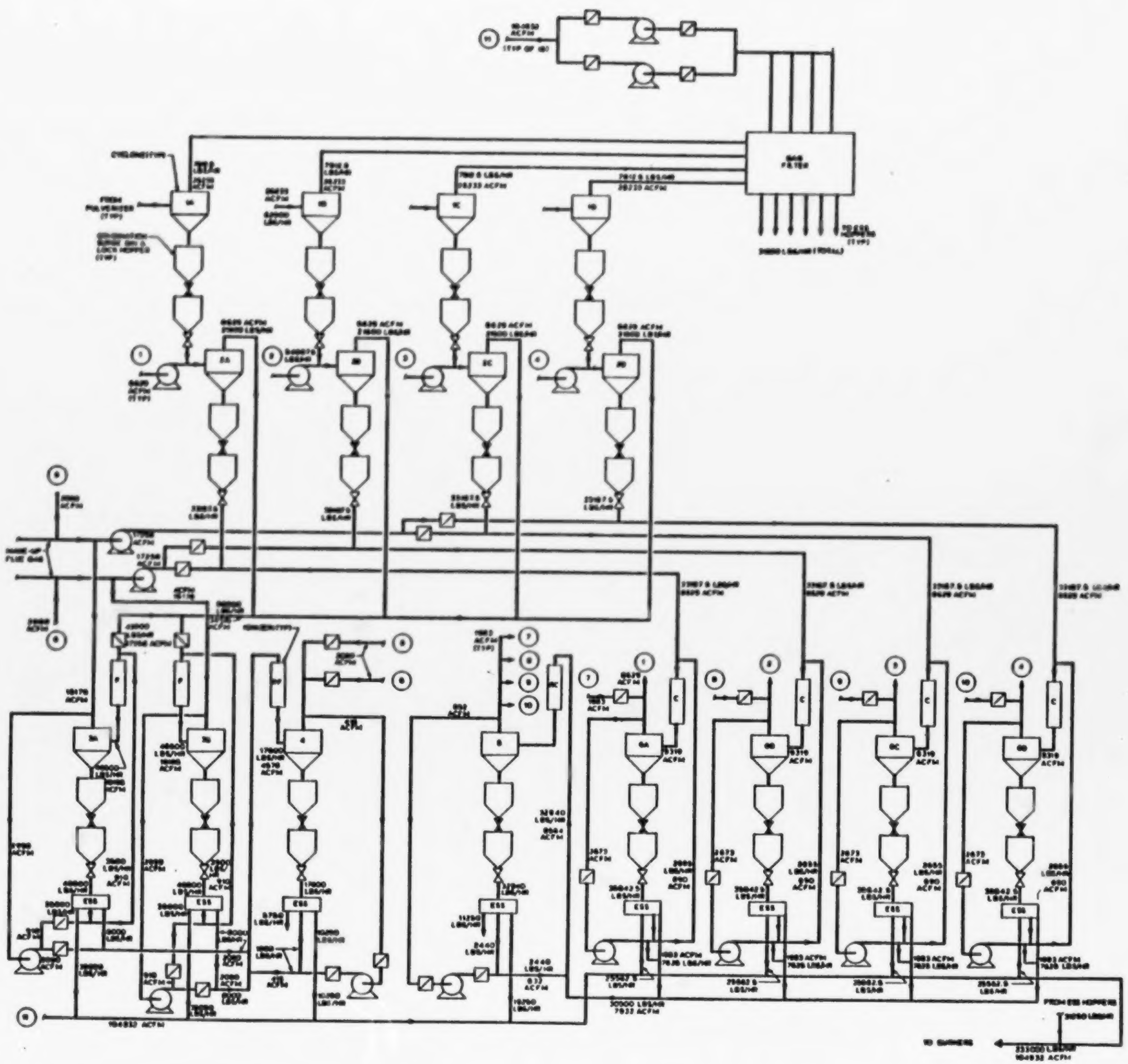
BAG FILTER
MAKE-UP FLUE GAS
ESS
C
6A
6C
5
4
3A
23167.5 LBS/HR
9629 ACFM
5316 ACFM
2673 ACFM
1983 ACFM
7626 LBS/HR
32940 LBS/HR
2440 LBS/HR
30000 LBS/HR
7833 ACFM
FROM ESS HOPPERS
TO CHIMNEYS
233000 LBS/HR
164832 ACFM

Figure D-1. Mass Balance - AED Coal Cleaning Study

Reproduced from best available copy.

System Design

a. System Design: Installation at an Existing Electric Power Plant --

The Mass Balance of the coal cleaning system, (as described in the Sections "BASIS" and DISCUSSION") is provided in Figure D-1.

As previously mentioned, a detailed engineering effort was beyond the scope of this study. Therefore, no attempt at system optimization could be performed. However, an effort was made to provide the system turn-down capability, redundancy and flexibility required to insure power generation would not be limited by this system.

This coal cleaning system is assumed to be installed in an existing plant presently using a direct-fired pulverized coal (PC) system. Direct-fired PC units would almost certainly represent the majority of existing 125 ton per hour (250 MW) units.

For the washed No. 4 Powhatan coal, Btu recovery of 97 percent has been measured and calculated, which requires an increase of coal feed to the pulverizers of approximately 3 percent and requires an increase in coal feed that would be allowable in most installations. For each particular installation identified, the increase in coal feed will be calculated after measuring the Btu recovery obtained with the use of the specific coal or blend of coals.

The coal cleaning system considered utilizes four (4) primary cyclones (1A, B, C, and D), each receiving the total primary air/coal mixture from one of the four existing pulverizers. The primary cyclones separates the ultrafine (less than 20 micron) coal and hot primary air from the remaining coal feed and convey the ultrafine coal/air mixture to a bag filter, where final separation of the primary air and ultrafine coal is accomplished.

Ultrafines from that bag filter are gravity fed to the six (6) electrostatic separator ESS hoppers where they are combined with the processed coal and distributed to the burners (an ESS hopper is supplied as part of each electrostatic separator).

The hot, primary air is conveyed via sixteen (16) individual lines to feed headers from the six (6) ESS hoppers where it is used to convey the processed coal product to the burners. The processed coal is discharged from the ESS hoppers via sixteen (16) rotary seal valves.

Coal is discharged from the bottom of the primary cyclone separators via surge bins and lock hoppers and entrained in a closed, pressurized flue gas system where it is transported by four (4) blowers to the secondary cyclone separators (2A, B, C, and D). There are four secondary cyclone separators, one for each pulverizer/primary cyclone separator.

The coal is separated into coarse/fine fractions in the secondary cyclone separators. The fine fraction is discharged with the flue gas from the top of each cyclone and conveyed through two (2) fine particle ionizers.

The coarse fraction is discharged from the bottom of each cyclone via surge bins and lock hoppers where it is released into the pressurized flue gas system and transported via two (2) 50 percent capacity blowers through four (4) coarse particle ionizers.

Coal leaving each fine and coarse particle ionizer travels through individuals cyclone separators (3A, B, and 6A, B, C, D, respectively) where the flue gas and coal is separated. The flue gas is returned to various blowers in the flue gas system to be used as the transport media. The coal is discharged from the bottom of each cyclone via surge bins and lock hoppers to the six (6) electrostatic separators. Each ESS contains eight rolls.

NOTE

THE MASS BALANCE SHOWN IN FIGURE 1 DEPICTS THE EIGHT (8) ROLLS OF ONE (1) ELECTROSTATIC SEPARATOR, NOT INDIVIDUAL SEPARATORS. THE ACTUAL COAL DISCHARGED FROM CYCLONE SEPARATORS 3A, B, 4, 5, 6A, B, C, and D IS SPLIT INTO SIX (6) LINES EACH, OR A TOTAL OF FORTY-EIGHT (48) LINES, EIGHT (8) FOR EACH ESS.

Discharges from ESS rolls associated with cyclones 3A, B, and 6A, B, C, D are each split into three flow paths. One is a cleaned coal product flow path where the processed coal is conveyed to the burners. The second is a "recycle" flow path where the processed coal is returned to its respective ionizer via a blower for reprocessing. The third is a "rejects" flow path where the solids, because of their constituents, are conveyed to either an additional fine or coarse particle ionizer depending on their original processing (i.e., solids rejects originally processed via fine particle ionizers are sent to a separate reject fine particle ionizer and coarse rejects originally processed by coarse particle ionizer are sent to a separate coarse reject particle ionizer).

The solids leaving the coarse and fine reject particle ionizers are processed through individual cyclone separators (4 and 5) where flue gas is removed and recycled into the closed flue gas system. The solids are discharged from the cyclone separators via surge bins and lock hoppers to the electrostatic separators.

Discharges from ESS rolls associated with cyclones 4 and 5 are split into three (3) flow paths. One is a cleaned coal product flow path where the processed coal is conveyed to the burners. The second is a recycle flow path where the coal is recycled to its respective ionizer for reprocessing. The third is solid waste discharge containing the rejected sulfur, ash, and some coal.

Six electrostatic separators, each having eight rolls, were used for this study. The number of electrostatic separators actually selected will affect system design and building size.

The number of blowers, cyclones and ionizers actually used will require a detailed engineering analysis to determine whether alternate arrangements would provide a reduction in cost or an increase in flexibility.

b. System Design: Installation at a Coal Mine --

The AED system, installed at a coal mine, will be similar to the design for installation at an electric power plant, but will require the addition of (1) pulverizing equipment and (2) a briquetting system. The balance of the system will be substantially the same in both types of installations. There will be no requirement for lengthy runs of ducting from the pulverizers to the classifiers and separators--and return--because the system layout will be more compact.

In the case of retrofitting an AED Coal Cleaning System to an existing electric power plant, the AED system would be located as far away as 500 ft from the pulverizers and boilers. At a coal mine, the system would be laid out so that the individual components are close together, reducing considerably the costs of interconnections. This is reflected in the capital equipment allowances for the two types of systems.

The system required for installation at a coal mine will receive the run-of-mine coal into its crushing/pulverizing equipment, which will serve the very same function as the pulverizers in an existing electric power plant. Costs have been obtained from manufacturers of commercially available crushing/pulverizing equipment, and these are listed as portions of the capital and operating equipment costs for the coal mine system.

Installation of an AED Coal Cleaning System at a coal mine requires treating the resulting cleaned, pulverized coal so that it can be shipped to users economically and effectively. Consideration has been given to the shipment of the pulverized coal itself, and this has been rejected for the purposes of the present analysis. There are both German and Australian operations working at the present time at small scale, in which pulverized coal is blanketed with nitrogen and shipped either in special containers (Australia) or in tanks, tank trucks, and tank railroad cars. It was felt that this mode of operation would require an entire spectrum of new technology, equipment, and handling procedures and should not be considered at the present time. Instead, briquetting technology is well developed; and prices have been obtained from several sources which offer briquetters to the industry. Recent data from the DOE Ames, Iowa facility confirms that briquets can be made without binder. The output of this equipment is suitable for transportation in the same manner as ordinary coal--in railroad cars, trucks, etc. The product does withstand weather and can be received by electric power plants and other users in the same manner as ordinary coal.

The briquets can be stored in piles or bins, indoors or outdoors. Typically, they will be pulverized again at the power plant.

The cost of the system will be increased due to the requirement for pulverizing and briquetting. However, certain costs will be diminished--notably, the instrumentation required in an electric power plant to provide load-following capability, since this feature is unnecessary in the coal mine system.

Material Handling

a. Material Handling: Installation at an Existing Electric Power Plant --

All pneumatic solids transport is accomplished in the dilute phase to provide the necessary air/flue gas flow rates to achieve particle separation as required in the cyclone separators.

A pressurized air/flue gas solids transport system was selected over a vacuum transport system for the following reasons:

1. All blowers will operate in the relatively "clean" air/flue gas atmosphere and thus perform reliably with a minimum of maintenance.
2. Primary air from the pulverizer outlets could be recovered and used to transport the cleaned coal product to the burners. This eliminates the necessity of using outside air and heating to 160°F.
3. Elimination of discharges to atmosphere from vacuum filters.

Lock hoppers were selected as the means to discharge solids from the cyclones to the pressurized air/flue gas stream. Proper sequencing of lock hoppers throughout the system is required to insure an even distribution of cleaned coal feed to the various components.

Rotary seal valves were selected as the means to discharge the cleaned coal to the coal feed lines. Due to the relatively low conveying pressures throughout the system, it may be feasible to use rotary seal valves in lieu of lock hoppers throughout the system resulting in a decrease in capital cost.

Carbon steel pipe with a minimum wall thickness of one-half inch was selected for solids transportation lines. This piping was assumed to be shop fabricated with long radius bends and a minimum use of elbows. Flanged fittings were used for all component connections except the electrostatic separators and welded joints for all piping.

b. Material Handling: Installation at a Coal Mine --

The chief difference between systems for application at the coal mine compared with those at electric power plants is in the use of nitrogen as an inerting gas instead of flue gas. The quantity required is for make-up purposes only, and it is judged that the costs involved will be substantially the same as those for electric power plant systems.

The costs of conveying the coal to the crusher/pulverizers and to and from the pelletizers are included in the costs of those types of equipment as listed in the capital investment costs section of this report.

Installation Location

a. Location of Installation with Respect to Powerhouse: Installation at an Existing Power Plant --

For the purpose of this study, it was assumed the coal cleaning system would be housed in an enclosed building and located adjacent to the powerhouse. If such a location is not possible, the estimate would require adjustment. Some factors that would influence the estimate for an alternate location are:

1. Existing Plant Roadways
2. Existing Rail Spurs
3. Land Contour
4. Soil Condition
5. Climate - possibly no enclosed building required for a southern climate.

b. Location of Installation with Respect to Powerhouse: Installation at a Coal Mine --

For the purpose of this study, it was assumed that the coal cleaning system would be partially housed in an enclosed building at approximately the same cost as for the electric power plant application. Some of the other considerations for siting the plant will be similar to the electric power plant case.

However, in general, there will be more space available for the installation of a system. It is assumed that there will be no charge for acquisition of land for the system.

Special Considerations

a. Preparation of Make-up Flue Gas: Installation at an Existing Electric Power Plant --

Make-up flue gas must be added to the closed circulation system in which the flue gas transports the coal through the coal cleaning system. The small quantity of flue gas must be supplied at a maximum temperature of 160°F and must be scrubbed before input to the coal cleaning system in order to remove acid gases which might otherwise cause corrosion. A tiny auxiliary scrubber may be used for this purpose, if an FGD scrubber is not being used on the site. Alternatively, an inert gas supply such as nitrogen could be used.

b. Nitrogen Blanketing System: Installation at a Coal Mine --

A nitrogen blanketing system will be required to prevent and eliminate any fire hazard in the processing of the pulverized coal. As mentioned above, it is assumed that the cost of this system will be approximately the same as that for a flue gas blanketing system that has been included in electric power plant applications. Nitrogen make-up will be due only to leakage, and this will be a very small cost compared with any of the other elements in the system.

System Controls

a. System Controls Including Load Follow Capability: Installation at an Existing Electric Power Plant --

If the unit selected for this installation is intended to have load following capability, the ability of the coal cleaning system to respond accordingly will require further analysis. Since this is located between the pulverizers and burners, and because of the quantity of coal being conveyed throughout the system, an inherent time lag would exist between the pulverizers and burners unless proper control logic can be integrated with the burner management system.

b. System Controls Including Load Follow Capability: Installation at a Coal Mine --

For the coal mine application, there is no requirement for load following capability. Clearly, load following is irrelevant for the coal mine application.

Solid Waste Disposal

a. Solid Waste Disposal: Installation at an Existing Electric Power Plant --

The disposal of solid wastes generated from the AED advanced coal cleaning system at an existing power plant is expected to be accomplished in a manner similar to the disposal of coal ash wastes. The physical and chemical nature of the AED coal cleaning wastes are somewhat different from typical coal ash wastes and must be fully characterized to establish final design criteria and permitting requirements for incorporation into the coal ash landfill disposal area. Total waste quantities will increase slightly, with a proportionate decrease in the life of the disposal facility, at a power plant without FGD, and will decrease (compared to a feed coal of equal sulfur content) at a plant with FGD.

Regulatory requirements for incorporation of the AED coal cleaning system wastes into the power plant's coal ash landfill or possibly a separate landfill are anticipated to be similar to those for coal ash wastes. Both wastes are currently categorically excluded from being hazardous wastes and are thus not regulated under Subtitle C, Hazardous Waste Management, of the Resource Conservation and Recovery Act (RCRA) regulations. Fly ash, bottom ash, slag, and flue gas emission control wastes generated from the combustion of coal or other fossil fuels are excluded by 40CFR261.4(b)(4). The AED coal cleaning wastes are excluded by a mining waste exclusion for "solid waste from the extraction, beneficiation, and processing of ores and minerals, including coal...." (40CFR261.4(b)(7)). The EPA is currently reviewing the mining waste exclusion to clarify "processing" and is expected to limit the types of processing wastes which remain excluded. Further definition of "beneficiation" versus "processing" is also likely. The impact of potential changes on the AED coal cleaning wastes cannot be determined at this time.

The incremental cost for the disposal of the AED coal cleaning wastes must be evaluated on a site specific basis because they can vary significantly. Power plants with ample onsite disposal capacity may not be significantly affected while power plants with contracted offsite disposal in states with restrictive disposal requirements may incur significant costs. At other power plants, plans for a new disposal area may have to be expedited.

Waste utilization as a by-product has potential to partially offset or eliminate disposal costs. AED has determined that, in the view of the sulfur and mineral content of the solid waste, there is an interest in these wastes as raw materials for the chemical industry. A future part of the AED program is to develop this market in order to convert a cost for waste disposal into a by-product credit.

It is also possible that the AED coal cleaning wastes could be transported back to the originating coal mine for disposal thereby eliminating any significant impact on the power plant ash disposal area.

b. Solid Waste Disposal: Installation at a Coal Mine --

The coal cleaning wastes would be generated at the coal mine where they can be disposed without offsite transportation. The cost of AED coal cleaning waste disposal at the mine has not been determined since it is specific to the type of mining operation and its location.

As described in Section 6.a., the waste is excluded from regulation as a hazardous waste.

Air Pollution Control

a. Effects on Air Pollution Control Equipment: Installation at an Existing Electric Power Plant--

Use of the AED process to reduce the sulfur and ash content of coal will most certainly have an effect upon existing particulate control equipment. Any existing power plant considering the use of the AED process will most likely be controlling particulate emissions with an electrostatic precipitator (ESP).

The collection efficiency of an ESP is affected by many variables including the physical/chemical nature of the flue gas and the fly ash, as well as quantities of the same. The AED system will reduce the total amount of fly ash collected by electrostatic precipitators. A substantial portion of the ash that would ordinarily be generated is collected by the AED equipment prior to combustion. This will reduce the overall load on the precipitator system.

b. Air Pollution Aspects of the Installation at Coal Mine --

The system that will be installed at coal mines will not create any air pollution control problems. Likewise, none will be eliminated. Consequently, it will not be necessary to include any costs for air pollution control.

Emissions Monitoring Requirements

a. Emissions Monitoring Requirements: Installation at an Existing Electric Power plant

Current EPA New Source Performance Standards (NSPS) for utility boilers require that a minimum percent reduction in SO_2 emissions be achieved as well as an absolute limit on SO_2 emissions. Use of the AED process either alone or in conjunction with additional SO_2 controls, will require that the coal sulfur content be accurately measured prior to entering the AED process equipment. Therefore careful consideration should be taken to allow for the inclusion of a coal sampling location upstream of the AED process where coal samples can be taken accurately and conveniently without disrupting the process. This sampling location should be upstream of the pulverizers if it is expected that they will reject any sulfur bearing fraction of the coal.

b. Emissions Monitoring Requirements: Installation at a Coal Mine --

Emissions monitoring will not be relevant to coal mine installations.

Permitting

a. Permitting: Installation at an Existing Electric Power Plant--

The permitting requirements associated with the use of the AED process will be highly site specific. The effect of the use of this process will be dependent upon many factors, for example, whether the plant is new or existing; whether the plant is a utility or industrial facility; geographic location of the plant; and the ultimate goal of using the AED process, i.e., to reduce overall emissions at a plant or to hold emissions constant with a fuel switch, etc. Many factors have to be evaluated prior to determining which permits are required for a given plant modification, and various permit requirements cannot be determined until site specific details are available. The decision to use the AED process for a particular plant could affect permitting anywhere from very minor to major requirements. Any permitting efforts will have to be evaluated on a site specific case-by-case basis.

b. Permitting: Installation at a Coal Mine--

Obtaining permits to operate AED coal cleaning systems should present fewer problems than obtaining the same permits for conventional coal cleaning operations. No water is used in the system so that the discharges are solid wastes only. No air pollution nor odors are created. Such systems should conform with the known federal and state regulations.

RESULTS

Installation at an Existing Electric Power Plant

The results of this study are summarized in Tables D-1 through D-4. The estimated costs of engineering services are provided and include the following:

1. Engineering and design of the coal cleaning building
2. Detailed system engineering and design including all necessary electrical and control work
3. Building, heating, ventilation, and fire protection
4. Purchase specifications for all required equipment, excluding ionizers and electrostatic separators

Installation at a Coal Mine

The results of this study are summarized in Tables D-5 through D-8. The estimated costs of engineering services are provided and include the following:

1. Engineering and design of the coal cleaning building
2. Detailed system engineering and design including all necessary electrical and control work
3. Building, heating, ventilation, and fire protection.
4. Purchase specifications for all required equipment, excluding ionizers and electrostatic separators. Included in the coal mine installation is pulverizing equipment (complete with necessary auxiliaries such as conveyors, cyclones, bag house collectors and also briquetting equipment, together with appropriate auxiliaries such as conveyors.

The engineering effort is estimated to be 6 to 9 months duration with construction following and being a twelve to fourteen month effort.

Estimated power consumption is based on the coal cleaning system operating at 6,000 hours per year.

Since a specific site has not been identified, costs for travel to the site have not been included. It is estimated that approximately fifteen 2-day trips will be required.

All costs are in January 1980 dollars. Costs of escalation and interest during construction have not been included. Should a particular schedule for engineering and construction be identified, costs shown in Table 8 should be adjusted accordingly and interest during construction added.

The system design and associated costs do not have any "load follow" capabilities because this is irrelevant in a coal mine installation. Thus, costs have been reduced by eliminating some of the controls and interim storage capacity.

Table D-8 provides cost in terms of:

1. dollars per ton and
2. dollars per Btu.

TABLE D-1

ADVANCED ENERGY DYNAMICS

COAL CLEANING SYSTEM

INSTALLATION AT AN EXISTING ELECTRIC POWER PLANT

ESTIMATED DIRECT SYSTEM

(January, 1980 Dollars)

DESCRIPTION	COSTS ($)		
	MATERIAL	LABOR	TOTAL
Cyclone Separators	135,000	25,100	160,100
Ionizers	200,000	6,200	206,200
Electrostatic Separators	1,506,700	90,000	1,596,700
Blowers and Motors	91,400	18,200	109,600
Lock Hoppers and Surge Bins	448,500	40,600	489,100
Rotary Seal Valves	765,000	28,800	793,800
Bag Filter	150,000	10,000	160,000
Piping, Valves and Fittings	533,800	1,478,100	2,011,900
Modifications to ESS	402,600	-	402,600
Electrical (Power)	279,000	312,000	591,000
Instrumentation and Controls	160,000	102,000	262,000
Structural - Equipment Bldg.	579,000	458,000	1,037,000
Building Heating, Ventilation and Fire Protection	90,000	30,000	120,000
Building Lighting and Misc. Electrical	40,000	25,000	65,000
Total Direct Costs	5,381,000	2,624,000	8,005,000

TABLE D-2

ADVANCED ENERGY DYNAMICS

COAL CLEANING SYSTEM

FOR INSTALLATION AT AN EXISTING ELECTRIC POWER PLANT

ESTIMATED CAPITAL INVESTMENT COSTS
(January, 1980 Dollars)

DESCRIPTION	COSTS ($)		
	MATERIAL	LABOR	TOTAL
Total Direct Cost	5,381,000	2,624,000	8,005,000
Total Distributables	272,000	292,000	564,000
Total A/E Headquarters Costs	489,000	523,000	1,012,000
Allowance for Indeterminates	736,000	516,000	1,252,000
Total Estimated Installed Cost	6,878,000	3,955,000	10,833,000

TABLE D-3

ADVANCED ENERGY DYNAMICS

COAL CLEANING SYSTEM

FOR INSTALLATION AT AN EXISTING ELECTRIC POWER PLANT

POWER CONSUMPTION
129 TPH COAL FEED

Description	Power Consumption (kW)
Ionizers	31
Electrostatic Separators	83
Rotary Seal Valves and Lock Hoppers	14
Blowers	274
Total Power Required for System Operation	402

TABLE D-4

ADVANCED ENERGY DYNAMICS

COAL CLEANING SYSTEM

INSTALLED AT AN EXISTING ELECTRIC POWER PLANT

LIFE CYCLE COSTS, 30 YEAR BASIS

CAPITAL INVESTMENT (1980 $)	
Total Plant Investment	$10,833,000
Preproduction Costs	367,000
Interest During Construction	325,000
TOTAL CAPITAL REQUIREMENT	$11,525,000
FIXED OPERATING COSTS (per year)	
Operating Labor	0
Maintenance Labor (40% maint. cost)	197,100
Maint., Material (60% maint. cost)	306,600
Admin. and Support Labor	65,700
OPERATION AND MAINTENANCE/YR	$ 569,400
VARIABLE OPERATING COSTS	
Waste Disposal	not considered
Chemicals	none
Water	none
Additional Coal Feed Req'd.	$ 1,073,100
TOTAL COST/YR	$ 1,073,100
POWER COST/YR	$ 131,400
CAPITAL COSTS/YR	
Capital 11,525,000 ÷ 30	$384,000
Interest 12% x $\frac{11,525,000}{2}$ =	691,550
	$1,075,000

(cont.)

TABLE D-4 (Cont.)

TOTAL YEARLY COSTS

Fixed Operating Costs	$ 569,400
Variable Operating Costs	1,073,100
Power Cost	131,400
Capital Costs	1,075,000
TOTAL YEARLY COST	$2,849,000

TOTAL COAL UTILIZED 125 TPH x 8760 hrs = TONS/YR 1,095,000

$$\frac{2{,}849{,}000}{1{,}095{,}000} = \$2.60/\text{TON}$$

At 12,450 Btu/lb of Cleaned Coal, Cost of Cleaning is \$0.10 per 10^6 Btu.

TABLE D-5

ADVANCED ENERGY DYNAMICS
COAL CLEANING SYSTEM
INSTALLATION AT A COAL MINE

ESTIMATED DIRECT SYSTEM
(January, 1980 Dollars)

DESCRIPTION	COSTS ($)		
	MATERIAL	LABOR	TOTAL
Pulverizing Equipment*	2,750,000	250,000	3,000,000
Cyclone Separators	135,000	25,100	160,100
Ionizers	200,000	6,200	206,200
Electrostatic Separators	1,506,700	90,000	1,596,700
Blowers and Motors	176,000	35,000	211,000
Lock Hoppers and Surge Bins	448,500	40,600	489,100
Rotary Seal Valves	765,000	28,800	793,800
Bag Filter	150,000	10,000	160,000
Piping, Valves and Fittings	533,800	1,478,100	2,011,900
Modifications to ESS	402,600	-	402,600
Electrical (Power)	279,000	312,000	591,000
Instrumentation and Controls	160,000	102,000	262,000
Structural - Equipment Bldg.	579,000	458,000	1,037,000
Building Heating, Ventilation and Fire Protection	90,000	30,000	120,000
Building Lighting and Misc. Electrical	40,000	25,000	65,000
Briquetting Equipment**	1,100,000	250,000	1,350,000
Total Direct Costs	9,315,600	3,140,800	12,456,400

*Including feeders, mill, classifier, fan, baghouse, cyclones, ductwork.

**Including silos, conveyors, screening equipment and building.

TABLE D-6

ADVANCED ENERGY DYNAMICS

COAL CLEANING SYSTEM

FOR INSTALLATION AT A COAL MINE

ESTIMATED CAPITAL INVESTMENT COSTS
(January, 1980 Dollars)

DESCRIPTION	COSTS ($)		
	MATERIAL	LABOR	TOTAL
Total Direct Cost	9,315,600	3,140,799	12,456,400
Total Distributables	471,000	244,000	715,000
Total A/E Headquarters Costs	846,000	626,000	1,472,000
Allowance for Indeterminates	1,267,000	617,000	1,884,000
Total Estimated Installed Cost	11,900,000	4,627,000	16,527,000

TABLE D-7

ADVANCED ENERGY DYNAMICS

COAL CLEANING SYSTEM

FOR INSTALLATION AT A COAL MINE

POWER CONSUMPTION
167 TPH COAL FEED

DESCRIPTION	POWER CONSUMPTION (kW)
Pulverizers	1,200
Ionizers	31
Electrostatic Separators	83
Rotary Seal Valves and Lock Hoppers	14
Blowers	274
Briquetters	400
Total Power Required for System Operation	2,002

TABLE D-8

ADVANCED ENERGY DYNAMICS

COAL CLEANING SYSTEM

INSTALLED AT A COAL MINE

LIFE CYCLE COSTS, 30 YEAR BASIS

CAPITAL INVESTMENT (1980 $)	
Total Plant Investment	$16,527,000
Preproduction Costs	560,000
Interest During Construction	496,000
TOTAL CAPITAL REQUIREMENT	$17,583,000
FIXED OPERATING COSTS (per year)	
Operating Labor	240,000
Maintenance Labor (40% maint. cost)	203,000
Maint., Material (60% maint. cost)	315,000
Admin. and Support Labor	68,000
OPERATION AND MAINTENANCE/YR	$ 825,000
VARIABLE OPERATING COSTS	
Waste Disposal	not considered
Chemicals	none
Water	none
Binder, for Briquets	none
TOTAL COST/YR	$ 0
POWER COST/YR	$ 701,000
CAPITAL COSTS/YR	
Capital 17,583,000 ÷ 30	$ 586,000
Interest $12\% \times \frac{17,583,000}{2}$ =	1,055,000
	$1,641,000

(cont.)

TABLE D-8 (Cont.)

TOTAL YEARLY COSTS

Fixed Operating Costs	$825,000
Variable Operating Costs	-0-
Power Cost	701,000
Capital Costs	1,641,000
TOTAL YEARLY COST	$3,167,000
TOTAL COAL UTILIZED 125 TPH x 6000 hrs = TONS/YR	750,000

$$\frac{3,167,000}{750,000} = \underline{\$4.22/\text{ton}}$$

At 13,147 Btu/lb of Cleaned Coal, Cost of Cleaning is $0.157 per 10^6 Btu.